DIAGENETIC CHARACTERISTICS OF SELECTED SANDSTONES ABOVE, WITHIN, AND BELOW THE MEGACOMPARTMENT COMPLEX, ANADARKO BASIN, OKLAHOMA

By

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CHAPTER I

INTRODUCTION

General Statement

Most deep sedimentary basins in the world include a layered arrangement of at least two hydraulic systems (Powley, 1987, p. 1). In some basins, mainly onshore in the United States, a third hydraulic system is present. In these three-layered hydraulic systems, the shallowest and deepest systems are basin-wide, and pressures are subnormal to normal. The middle hydraulic system generally is not basin-wide and in this system are compartments of abnormally high pressures. Mechanisms of abnormal pressuring were described by Dickinson (1953), Powers (1967), Baker (1972), and Bradley (1975). These mechanisms include structural differentiation, clay diagenesis, aquathermal pressuring, compaction, compartmentation by seal-development, and combinations of these various mechanisms An example of a basin with three hydraulic systems is the Anadarko Basin; abnormally overpressured compartments are in the middle system. These compartments are a two-component subsystem that consists of porous and permeable rock surrounded by a seal. Geological processes that are important to the formation of these compartments are subsidence, sedimentation and diagenesis. The study of pore-pressure data and subsurface geological data from the Anadarko Basin indicates the presence of a basin-wide, overpressured, completely sealed compartment. The term *megacompartment complex* (MCC), was introduced by Al-Shaieb (1991) to describe this hydraulic system. The megacompartment complex is bounded by top, basal and lateral seals. It is approximately 240 km (150 mi) long, 110 km (70 mi) wide and is at least as thick as 4800 m (16,000 ft) (Al-Shaieb and others, 1993, p. 70). The top seal is 10,000 to 11,000 feet below the surface (Al-Shaieb and others, 1992, p. 210), whereas the basal seal is the Devonian Woodford Shale.

Objectives

The purpose of this investigation is to (1) determine the locations of sandstones above, below, and within the overpressured compartment; (2) estimate the amount of silica dissolved/precipitated within the sandstone(s); (3) describe the diagenetic changes among sandstones; (4) compare the petrography and diagenesis of sandstones to determine differences in pressure, cement, and porosity with depth; and (5) describe criteria that can be applied in other basins, to locate overpressured compartments where petroleum could be trapped.

Location of Study Area

The area of investigation includes townships ranging from T6N through T15N and R7W through R13W in parts of Caddo, Grady and Blaine counties, Oklahoma (Fig. 1). The study area is in the eastern portion of the Anadarko Basin (Fig. 2) which is bounded to the north by the Northern Oklahoma Platform, to the east by the Nemaha Uplift, to the west by the Sierra Grande and Apishapa Uplifts, and to the south by the Amarillo-Wichita Uplift (Fig. 3).

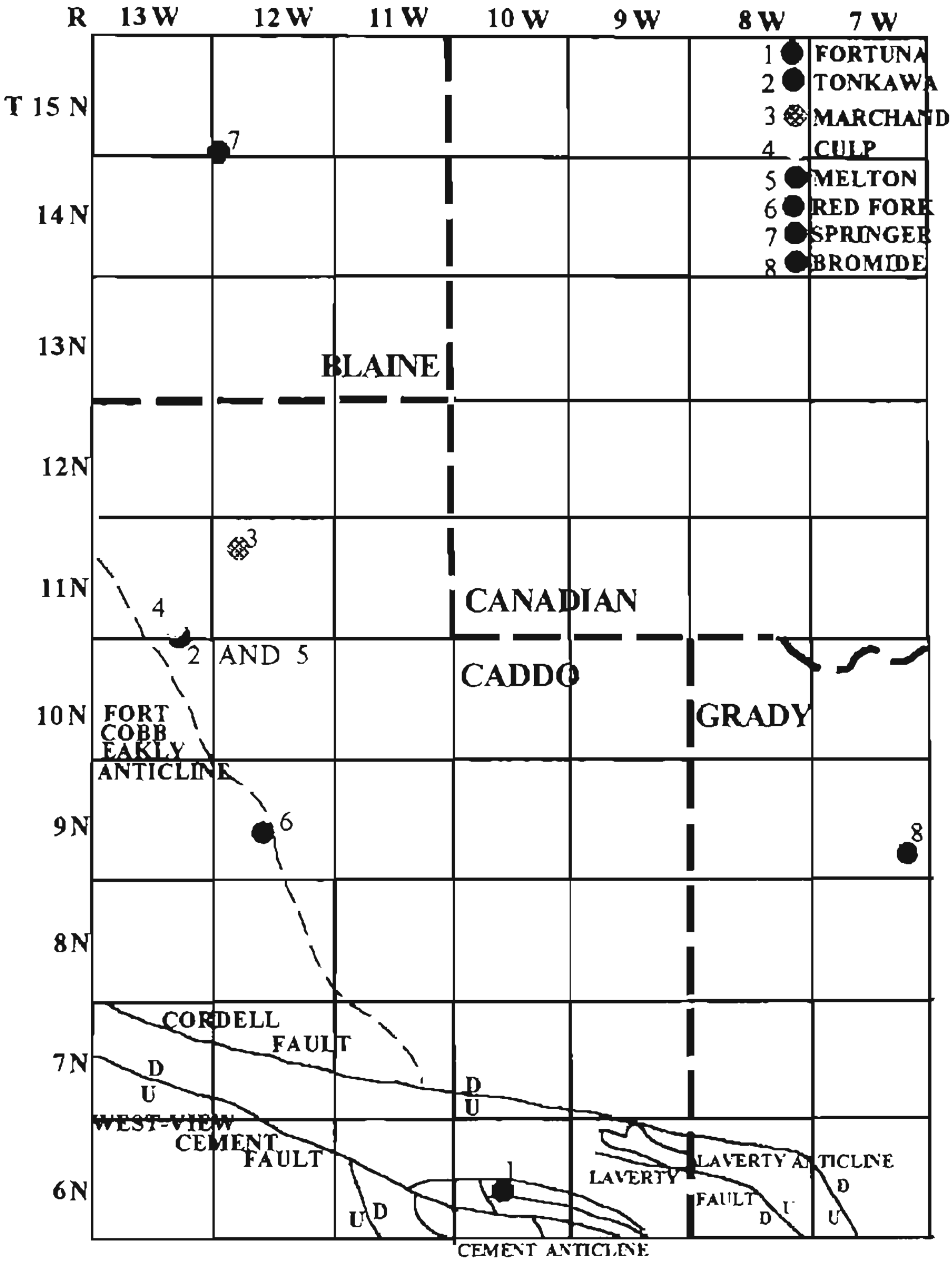


Figure 1. Location of study area and local structral features.

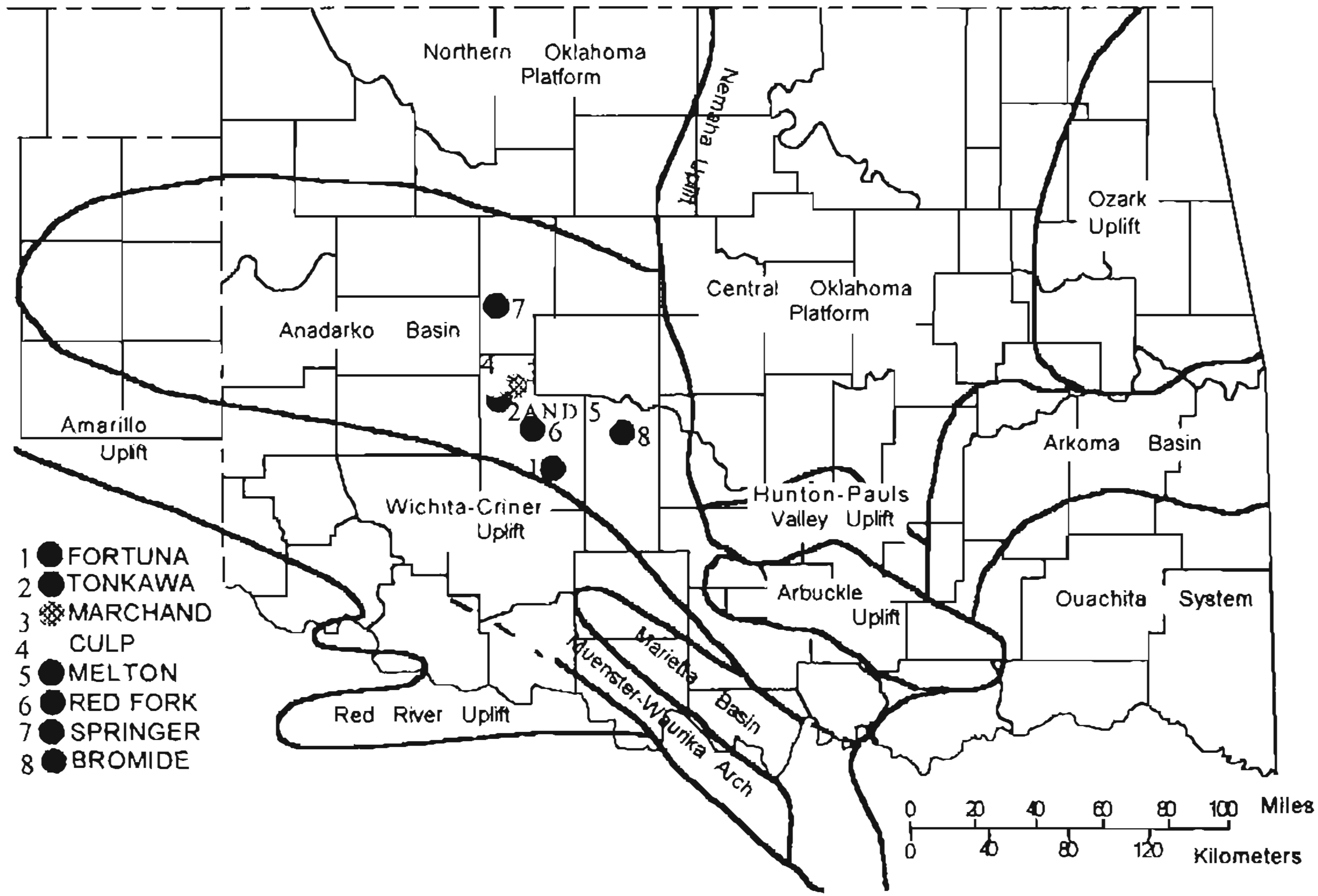


Figure 2 Structural element map of Oklahoma (from Al-Shaieb and Shelton, 1981) and location of the cored intervals studied

Figure 3. Structural element map of the Mid-Continent (modified from Rascoe and Adler, 1983; and Larson, 1971).

The Anadarko Basin is characterized by a broad, gently dipping cratonal shelf area on the northern flank and by a narrow, steeply dipping southern flank bounded by the Amarillo-Wichita Mountain frontal fault system. This frontal fault system is composed of westerly- to northwesterly-trending faults (Harlton, 1972, p 1545).

The northern portion of the study area is structurally simple whereas the southern portion of the area is faulted along the Amarillo-Wichita Mountain front, including the faulted Cement, Laverty, and Fort Cobb-Eakly anticlines (Fig. 1).

The Mountain View/Cement fault and the Cordell fault are two thrust faults of the frontal fault system within the study area. These long faults are subparallel to the Amarillo-Wichita Uplift and were formed during the rifting stage of the Southern Oklahoma Aulacogen (Harlton, 1972, p. 1545).

Method of Investigation

This analysis focused on similarities and variations in sandstones that transect vertically the top and basal seals within the Anadarko Basin. The location of study was based on the following factors: (1.) the location had to be in the smallest township-range area forming a vertical section with core data, and (2.) the location had to have cored formations above, below and within the megacompartment complex.

Internal features of the sandstones above, below and within the megacompartment complex were investigated through detailed petrologic logging of 365 feet of Bromide, Springer, Red Fork, Melton, Culp, Marchand, Tonkawa, and Fortuna sandstones combined.

Each core was sampled at several places, based upon lithology and variation in lithology, which was commonly evident as a change in color of sandstone in the core. The samples were then studied in further detail by thin-section petrography and x-ray diffractometry (Table 1).

Twenty-three thin-sections were described to aid in analysis of the composition of each formation. Thin-section petrography also was used to measure the amounts of cements, to identify porosity, and to isolate evidence of silica precipitation and dissolution. X-Ray diffraction was implemented to identify the clay mineral composition. Interpretation of the structure and formation of the megacompartment seal was made from these investigations.

TABLE 1

LIST OF SANDSTONES WITH
CORRESPONDING SAMPLE DEPTHS AND ANALYSIS

Depth (ft)	X-ray Diffraction	Evidence of Silica Precipitation/Dissolution	Analysis of Composition
Fortuna sandstone			
2,035	X	X	X
Tonkawa sandstone			
8,953	X	X	X
8,955	X	X	X
8,957	X	X	X
Marchand sandstone			
9,860	X	X	X
9,912	X	X	X
9,924	X	X	X
Culp sandstone			
10,395	X	X	X
10,403	X	X	X
Melton sandstone			
10,878	X	X	X

TABLE I (continued)

Depth (ft)	X-ray Diffraction	Evidence of Silica Precipitation/Dissolution	Analysis of Composition
Red Fork sandstone			
14,098	X	X	X
14,101	X	X	X
14,103	X	X	X
14,119	X	X	X
14,7135	X	X	X
14,144	X	X	X
14,147	X	X	X
Springer sandstone			
10,901	X	X	X
10,906	X	X	X
10,912	X	X	X
Bromide sandstone			
13,375	X	X	X
13,389	X	X	X
13,408	X	X	X

CHAPTER II

GEOLOGIC HISTORY

The geologic history of the Anadarko Basin has been discussed in detail by Rascoe and Adler (1983), Johnson and others (1988), (1988), and Johnson (1989). Information set out by these authors was used in the formulation of this chapter.

Several major stages of basin evolution controlled Paleozoic sedimentation in the Anadarko Basin. These stages are associated with the formation and evolutional history of the Southern Oklahoma Aulacogen.

Early to Middle Cambrian Episode

The first (rifting) stage was marked during Early and Middle Cambrian time by the development of marginal faults and downwarp associated with intrusive and extrusive igneous activity (Fig. 4) (Johnson and others, 1988, p. 326-327). In Middle Cambrian time seas transgressed to the north and west across the southern mid-continent onto what was to become the stable interior of the United States. Middle Cambrian carbonate rocks were deposited over the southern mid-continent as part of a vast shallow-water platform that stretched from New York to New Mexico (Johnson and others, 1988, p. 313). There is no rock record of late Middle to Late Cambrian sedimentation in the area of the Southern Oklahoma aulacogen, possibly because of continued igneous activity early in this stage.

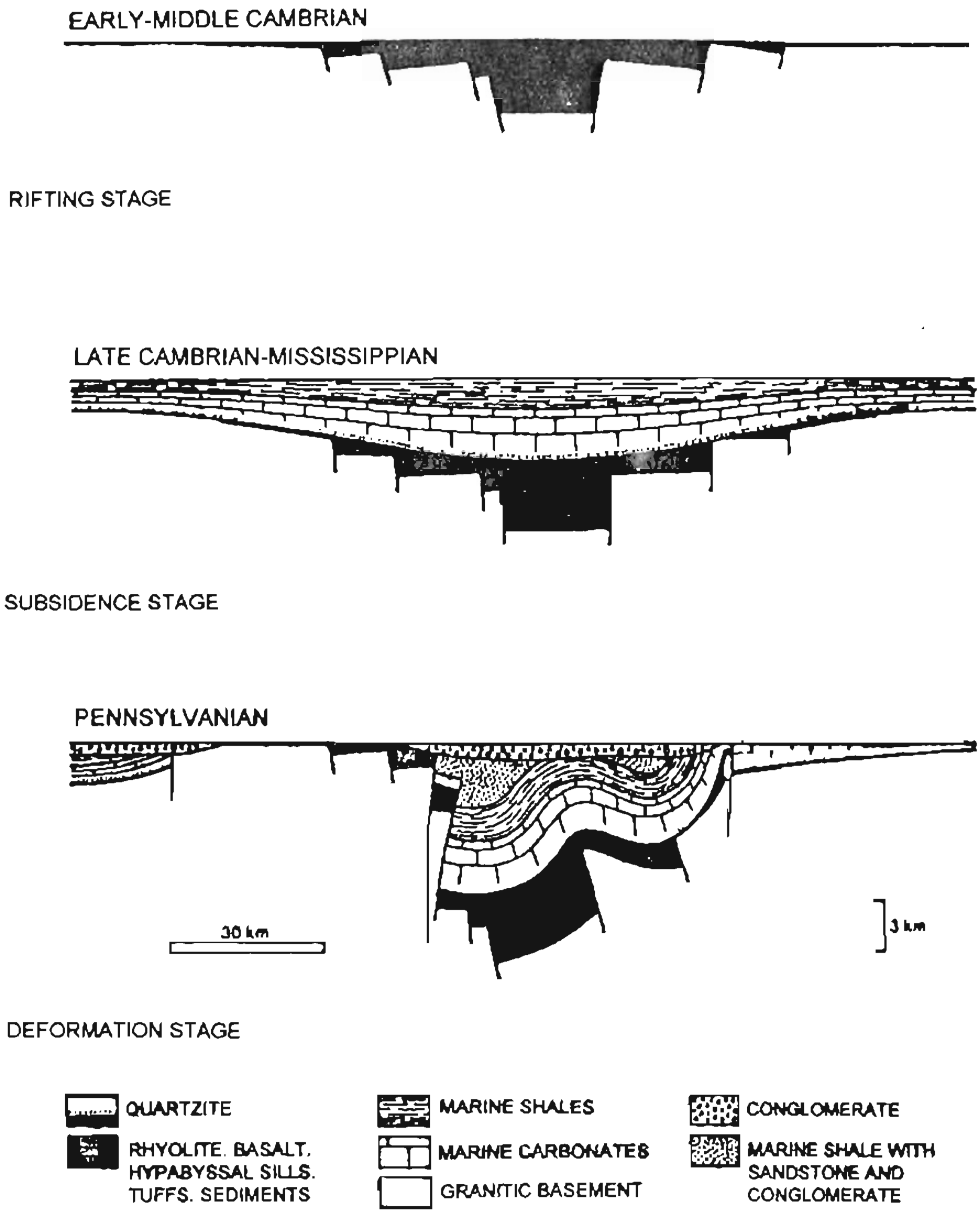


Figure 4. Series of transverse cross-sections showing evolution of the Southern Oklahoma Aulacogen (modified from Hoffman and others, 1974).

Late Cambrian to Middle Mississippian Episode

The second stage of subsidence, during Late Cambrian through middle Mississippian time, was characterized by downwarping and the accumulation of the thick carbonate sedimentary sequence (Fig. 4) (Johnson and others, 1988, p. 327).

Ordovician System

During the second stage of subsidence in Middle to Late Ordovician time, rapid subsidence was confined to the cratonic margins and the Anadarko Basin trend (Sloss, 1988, p. 31). Throughout the Oklahoma region the rocks from Middle Ordovician through Earliest Mississippian consist of fossiliferous shallow-water marine limestones and dolomites interbedded with clayey shales and quartzitic sandstones derived from northeastern and eastern sources (Fig. 5) (Johnson and others, 1988, p. 6).

Silurian and Devonian Systems

During the Early Silurian to Early Devonian interval the Anadarko region remained in open communication with southern seaways (Sloss, 1988, p. 33). In Devonian time, deposition was interrupted by two major epeirogenic uplifts, an Early Devonian Uplift and a Late Devonian Uplift (Fig. 6) (Johnson and others, 1988, p. 313). Both uplifts affected local structures on the flanks of the basin.

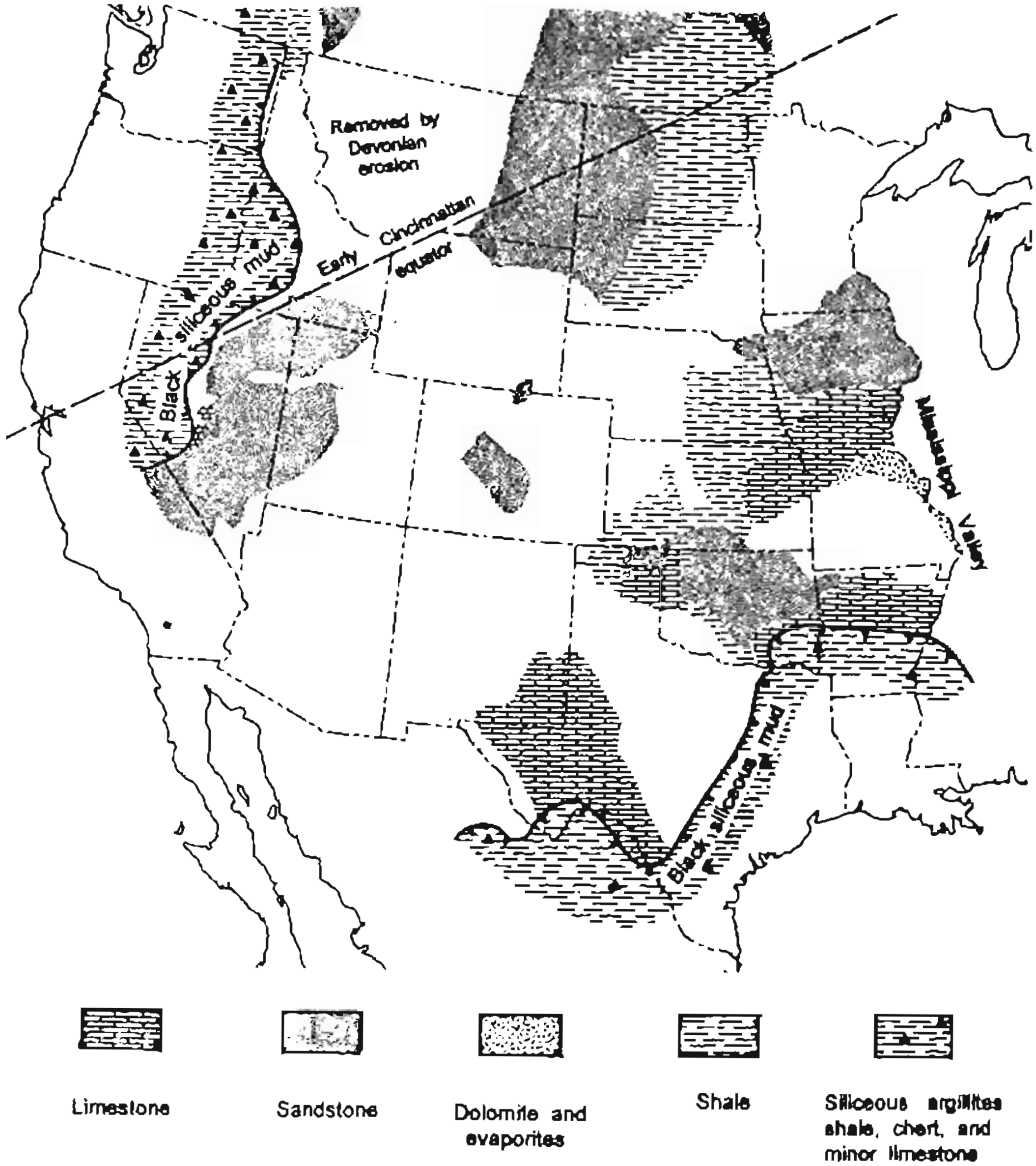


Figure 5. Map of Middle Ordovician lithofacies, western United States (from Ross, Jr., 1974).

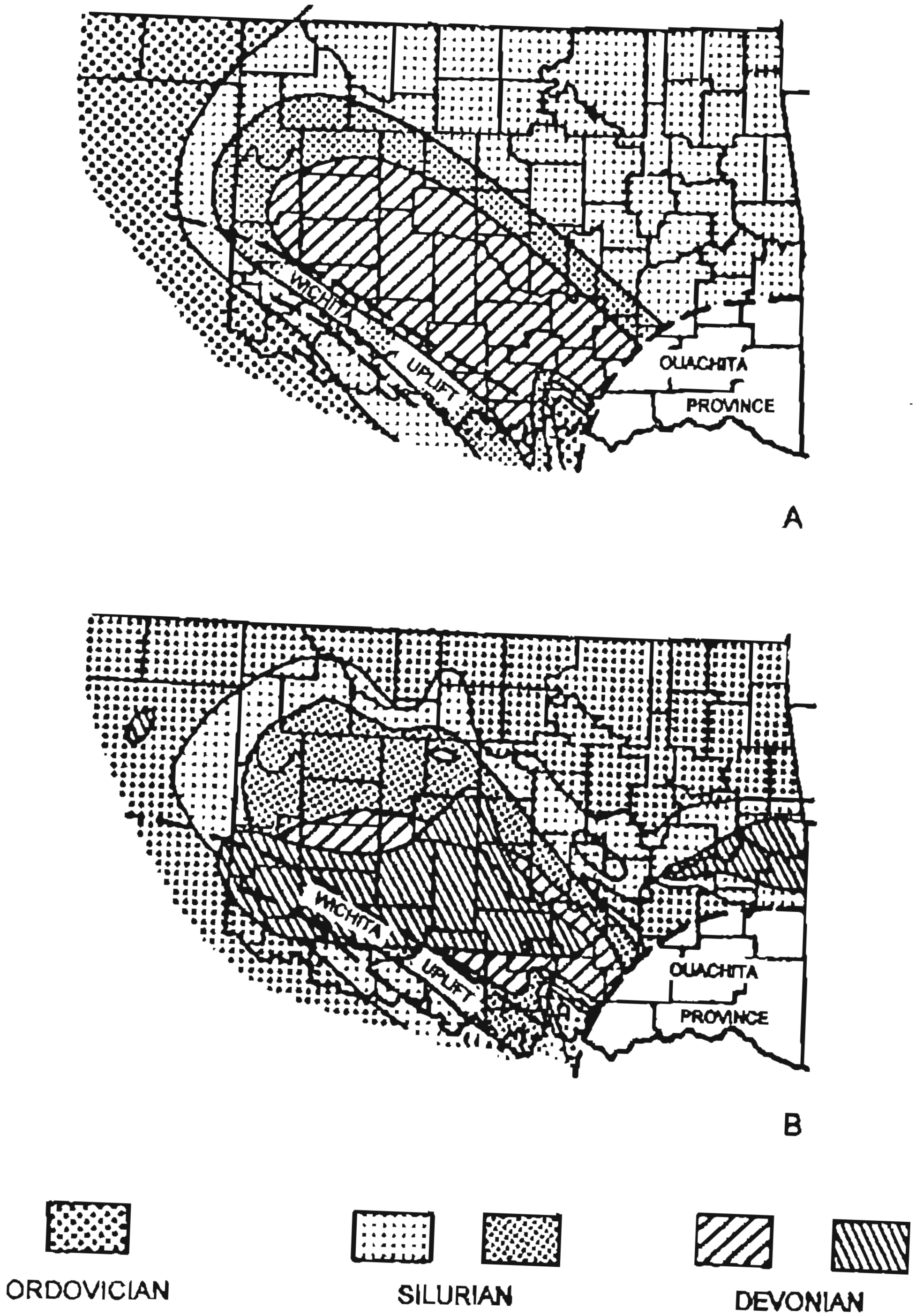


Figure 6. Paleogeologic map showing the distribution of strata in the Oklahoma region following two major epeirogenic uplifts. (A) shows middle Early Devonian, (B) shows Late Devonian strata (modified from Johnson and others, 1988).

Early to Middle Mississippian System

Epeirogenic movements continued throughout the southern midcontinent. Sediments deposited in the Anadarko Basin area consist mainly of shallow marine limestones, cherty limestones, and shales.

Late Mississippian and Pennsylvanian Episode

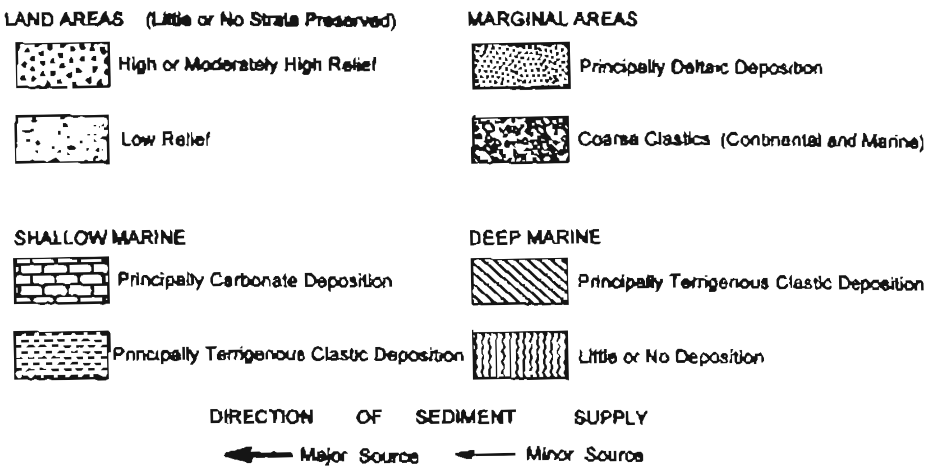
The third (deformation) stage during Late Mississippian and Pennsylvanian time was marked by development within the aulacogen of major elongated uplifts (e.g. Wichita and Criner Uplifts) in proximity to long and typically deep basins (e.g. Anadarko, Ardmore, and Marietta Basins), and the accumulation of a thick clastic sedimentary sequence (Fig. 4) (Johnson and others, 1988. p. 327).

Pre-Pennsylvanian Unconformity

An episode of widespread emergence and erosion created the "pre-Pennsylvanian unconformity" over the Mid-Continent. The Cambridge Arch and Central Kansas Uplift came into existence at this time (Fig. 3); structural folding was probably accompanied by eustatic lowering of sea level. Late Mississippian rocks were removed from shelf areas bordering the Anadarko and Arkoma Basins. Sediments of Early Pennsylvanian through Late Pennsylvanian (Morrowan to Missourian) age onlapped rocks ranging from Proterozoic to Late Mississippian (Rascoe and Adler, 1983, p. 980).

Pennsylvanian System

Morrowan Stage The top of the Mississippian System is well marked by the pre-Pennsylvanian unconformity in most parts of the southern mid-continent. The Mississippian-Pennsylvanian boundary is within the thick sequence of Springer and equivalent shales where sedimentation was uninterrupted in the deep part of the Anadarko Basin, toward which the Late Mississippian seas regressed. The contact of Morrowan and Chesterian rocks is typically difficult to determine; thus, strata of the Springer are often grouped with those of the Morrow. In the Early Pennsylvanian, seas trangressed toward the north and northwest and encroached upon adjacent shelf areas (Rascoe and Adler, 1983, p. 986). The Wichita-Amarillo block was uplifted along a series of westerly- to northwesterly-trending reverse faults with thrusting northward toward the rapidly sinking Anadarko Basin. Faulting began at the southeast end of the basin early in Morrowan time, persisted through the rest of the Pennsylvanian, and probably died out during the Early Permian. Orogenic movements of the Wichita-Amarillo block and of other positive elements surrounding the Anadarko Basin consisted only of faulting, folding, uplift and downwarping. No igneous or metamorphic activity accompanied the tectonism. During the early Morrow the source areas were from a north/northwestern direction and from the Amarillo-Wichita Uplift to the south (Fig. 7) (Rascoe and Adler, 1983, p. 988). The Transcontinental Arch (Fig. 3) was the source area of upper Morrow deposits (Fig. 7).



Explanation for figures 7-13.

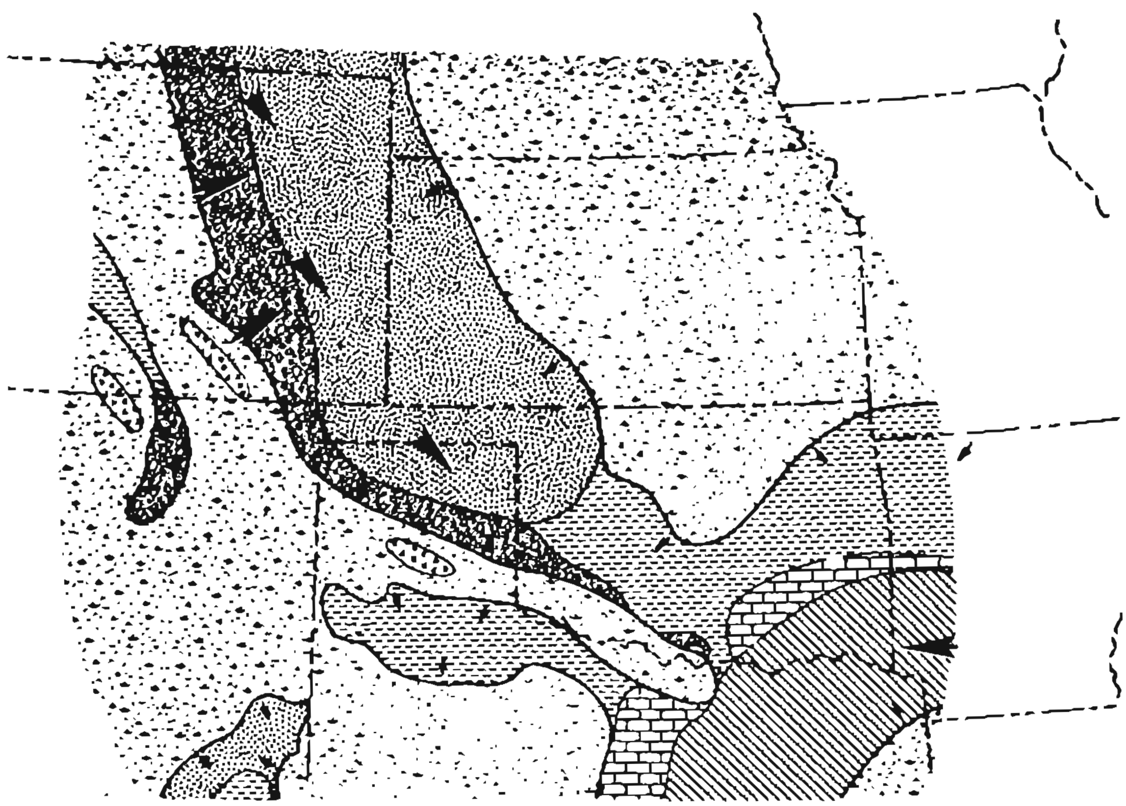


Figure 7. Generalized paleogeography and paleoenvironments of the Morrowan (from Moore, 1979).

Atokan Stage Atokan rocks in the Anadarko Basin consist of cyclic sequences of marine limestones and shales (Johnson and others, 1988, p. 9). Near the northern margin of the Amarillo-Wichita Uplift, Atokan limestones and shales grade abruptly into massive clastic deposits, which consist of granite, limestone, and dolomite fragments. This "granite wash" was the first granite wash deposited into the Anadarko Basin from the Amarillo-Wichita Uplift. The Anadarko and Arkoma Basins were separated in Atokan time by uplift of a series of narrow, north-trending fault block mountains along the Nemaha Uplift

Desmoinesian Stage Early Desmoinesian sediments were deposited during a major transgression onto the Kansas shelf. During the Early Desmoinesian the Amarillo-Wichita Uplift continued to shed coarse debris into the southern portion of the Anadarko Basin, whereas the northern portion of the basin was receiving clastics from a northerly source area (Fig. 8). During the Late Desmoinesian the source area from the north had ceased and a southerly, the Ouachita Foldbelt (Fig. 3), had begun depositing clastics into the Anadarko Basin (Fig. 9) (Moore, 1979, p. 9)

Mid Pennsylvanian Wichita Orogeny Tectonic events that comprise the Wichita Orogeny were the result of collision between the North American and South American plates from Morrowan into Desmoinesian time. This collision folded and faulted strata of the Ouachita Foldbelt, and was manifest in subsidence of the Anadarko Basin; the emergence of the Amarillo-Wichita Uplift, Apishapa Uplift, and Nemaha Uplift, and the uplift of the Cimarron Arch (Fig. 3).

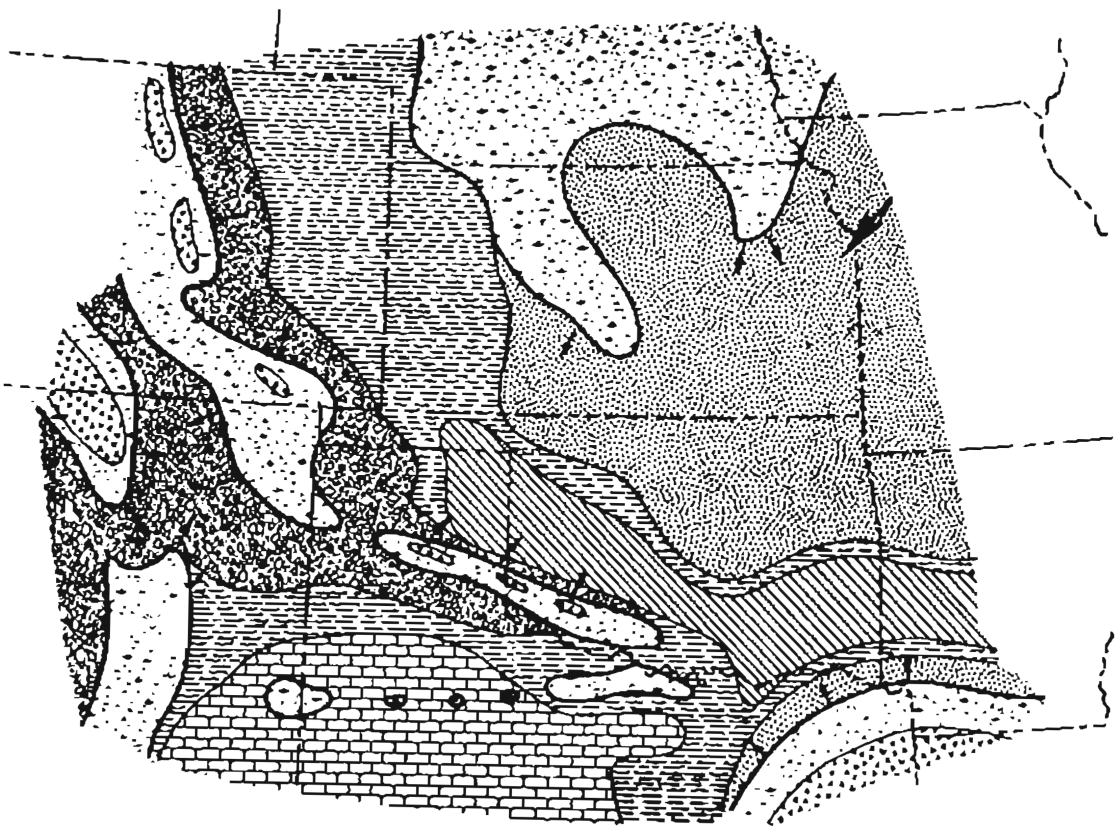


Figure 8. Generalized paleogeography and paleoenvironments of the Early Desmoinesian (from Moore, 1979).

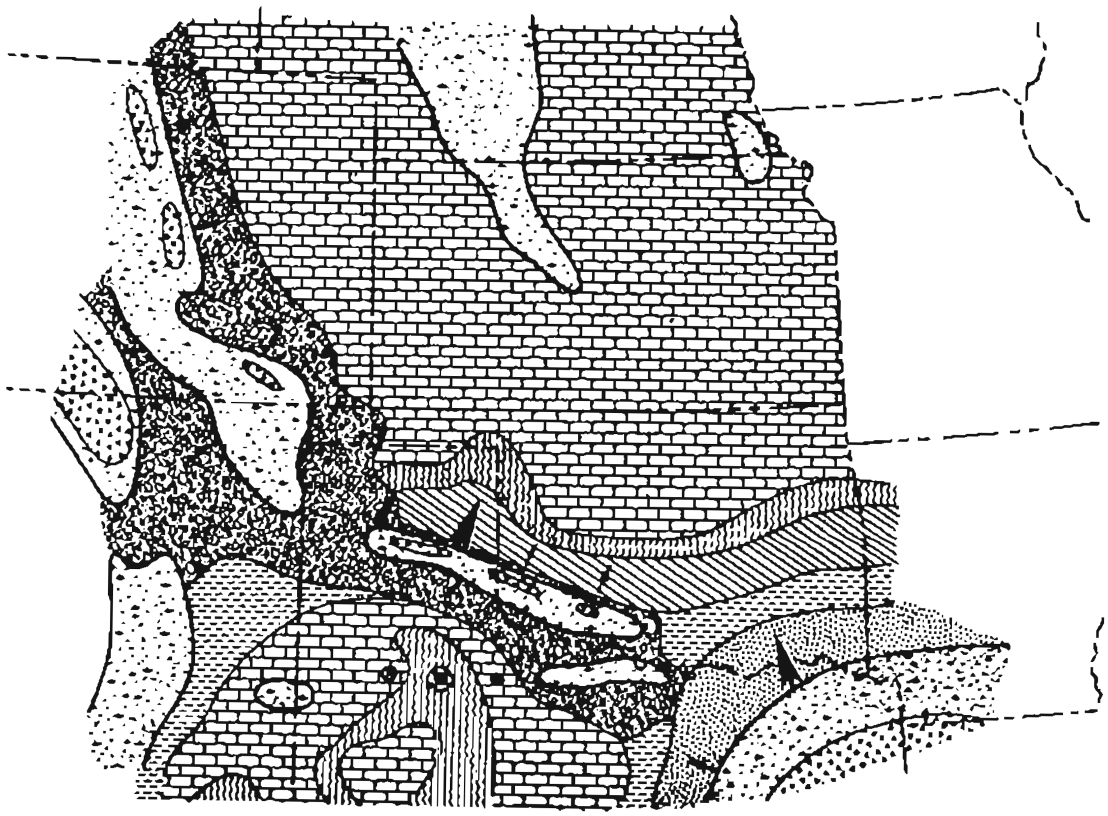


Figure 9. Generalized paleogeography and paleoenvironments of the Late Desmoinesian (from Moore, 1979).

Pennsylvanian strata of the region can be characterized as sequences of marine and nonmarine rocks that thickened in the rapidly subsiding basin. Thick wedges of terrigenous clastic sediments were shed from nearby uplifts; thinner carbonate sequences were deposited on shallow-water shelf areas distal to the uplifts (Johnson and others, 1988, p. 318).

Missourian Stage Marine transgression onto the Kansas shelf continued in Late Pennsylvanian time, and the Central Kansas Uplift and Nemaha Uplift were inundated. A west-to-east increase in sandstone content of the terrigenous clastic facies of the Missourian and progression from marine to marginal-marine environments indicate that the Ouachita Foldbelt was the source area of the clastic sediments.

On the northern flank of the Amarillo-Wichita Uplift the Missourian is composed of arkosic and carbonate "wash" sediments which were eroded from the uplift. The major positive tectonic elements active during Missourian time were the Arbuckle Uplift, from which conglomeratic debris was eroded; the Amarillo-Wichita Uplift, which was a source area of coarse detritus; the Apishapa Uplift, from which mostly fine-grained clastics were eroded; the Ouachita Foldbelt which was the source area of clastic sediments. and the southern part of the Central Kansas Uplift, which influenced the thickness of the Misssourian sediments deposited over it (Fig. 10, 11) (Johnson and others, 1988, p. 324).

Virgilian Stage In central Oklahoma, the Virgilian Stage consists of continental to shallow marine shales, sandstones, and mudstones, which grade westward into delta-

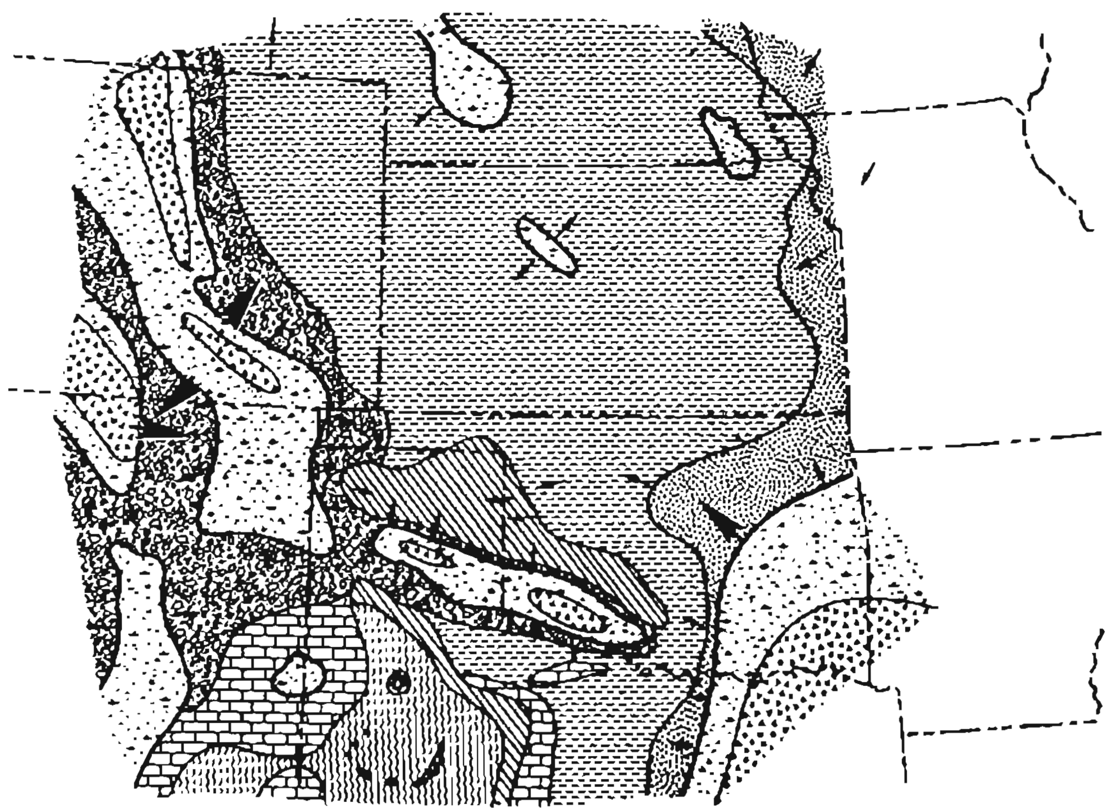


Figure 10. Generalized paleogeography and paleoenvironments of the Early Missourian (from Moore, 1979).

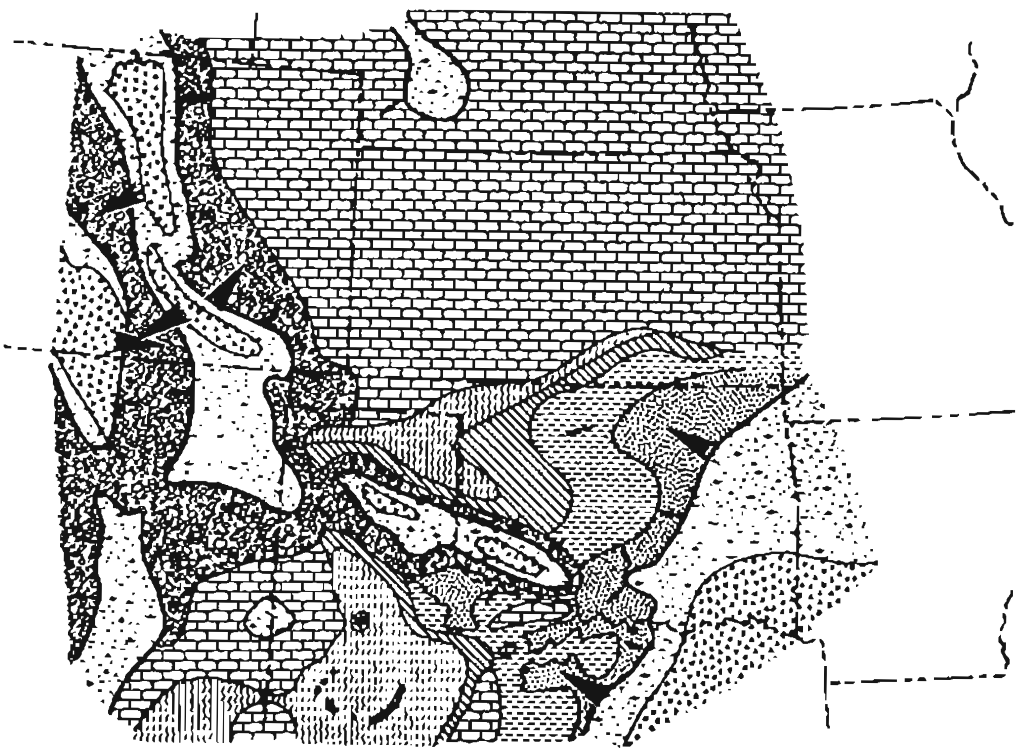


Figure 11. Generalized paleogeography and paleoenvironments of the Late Missourian (from Moore, 1979).

plain sandstones and prodelta shales. The Amarillo-Wichita Uplift remained a positive feature and coarse detritus was deposited along its northern margin. The Ouachitas continued to contribute clastics to the east side of the Anadarko Basin and the Arbuckle Mountains produced coarse detritus that was deposited in the southeast part of the basin (Fig. 12, 13). In southern Oklahoma the Arbuckle Orogeny marked the close of Pennsylvanian time (Rascoe and Adler, 1983, p. 996).

Permian

In Permian time, a well-defined seaway extended northward from west Texas across the western half of the southern mid-continent. Coarse clastics were eroded from the Ouachita Mountains on the east, the ancestral Rocky Mountains (Sierra Grande and Apishapa Uplifts) (Fig. 3) on the west, and the Amarillo-Wichita Uplift in the center (Johnson and others, 1988, p. 318).

Wolfcampian Stage

During Wolfcampian time shallow marine cyclic limestones and shales were deposited across the main seaway that extended southwest to northeast across the western half of the Anadarko Basin (Fig. 14). Clastic sediments were eroded from the Ouachita Mountains on the east, the Rocky Mountains on the west, and the remnants of the Amarillo-Wichita Uplift to the south (Johnson, 1989, p. 11).

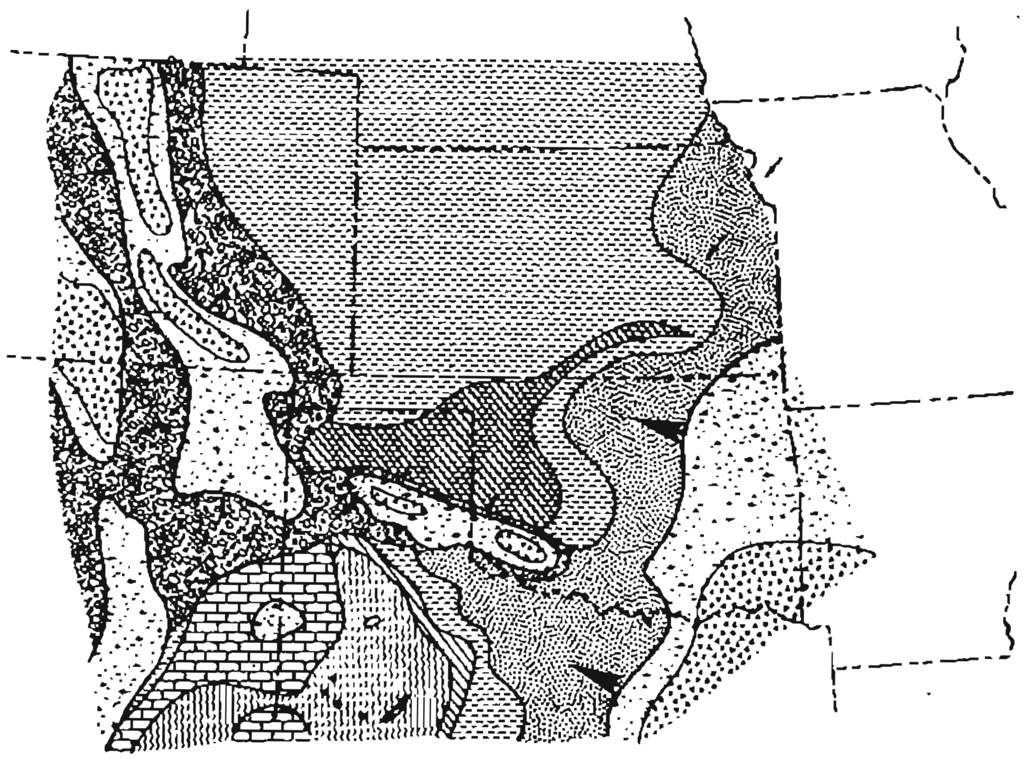


Figure 12. Generalized paleogeography and paleoenvironments of the Early Virgilian (from Moore, 1979).

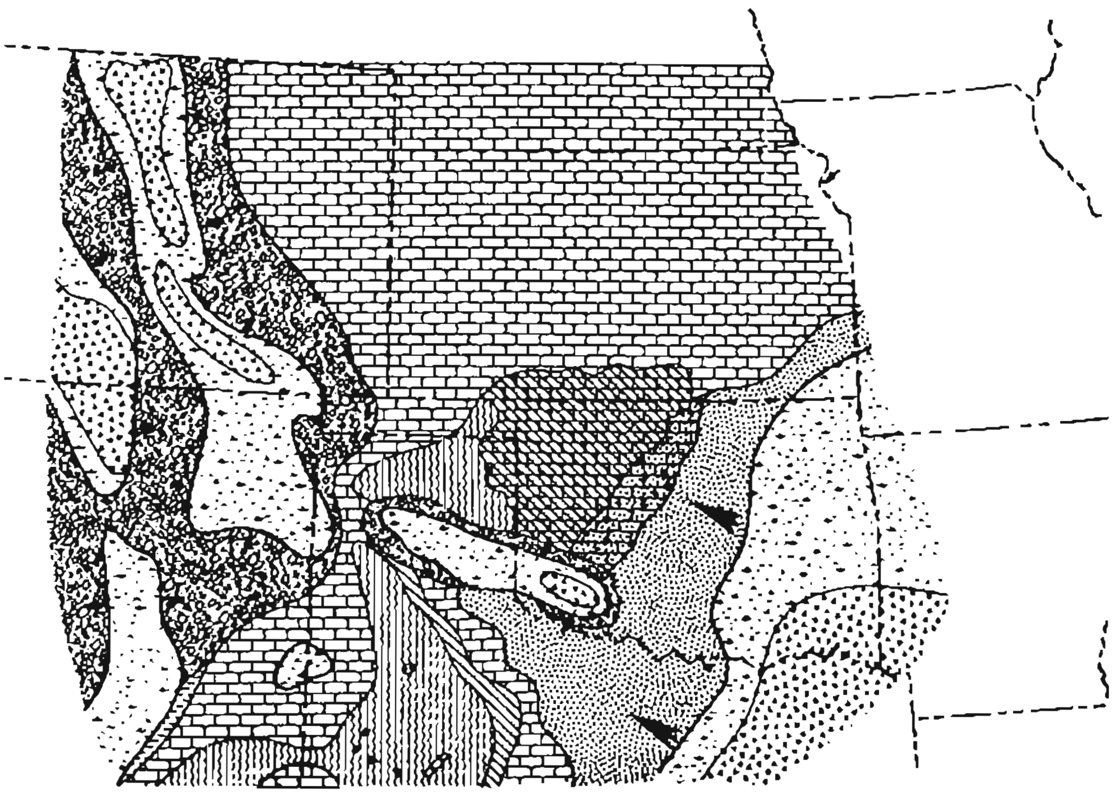


Figure 13. Generalized paleogeography and paleoenvironments of the Late Virgilian (from Moore, 1979).

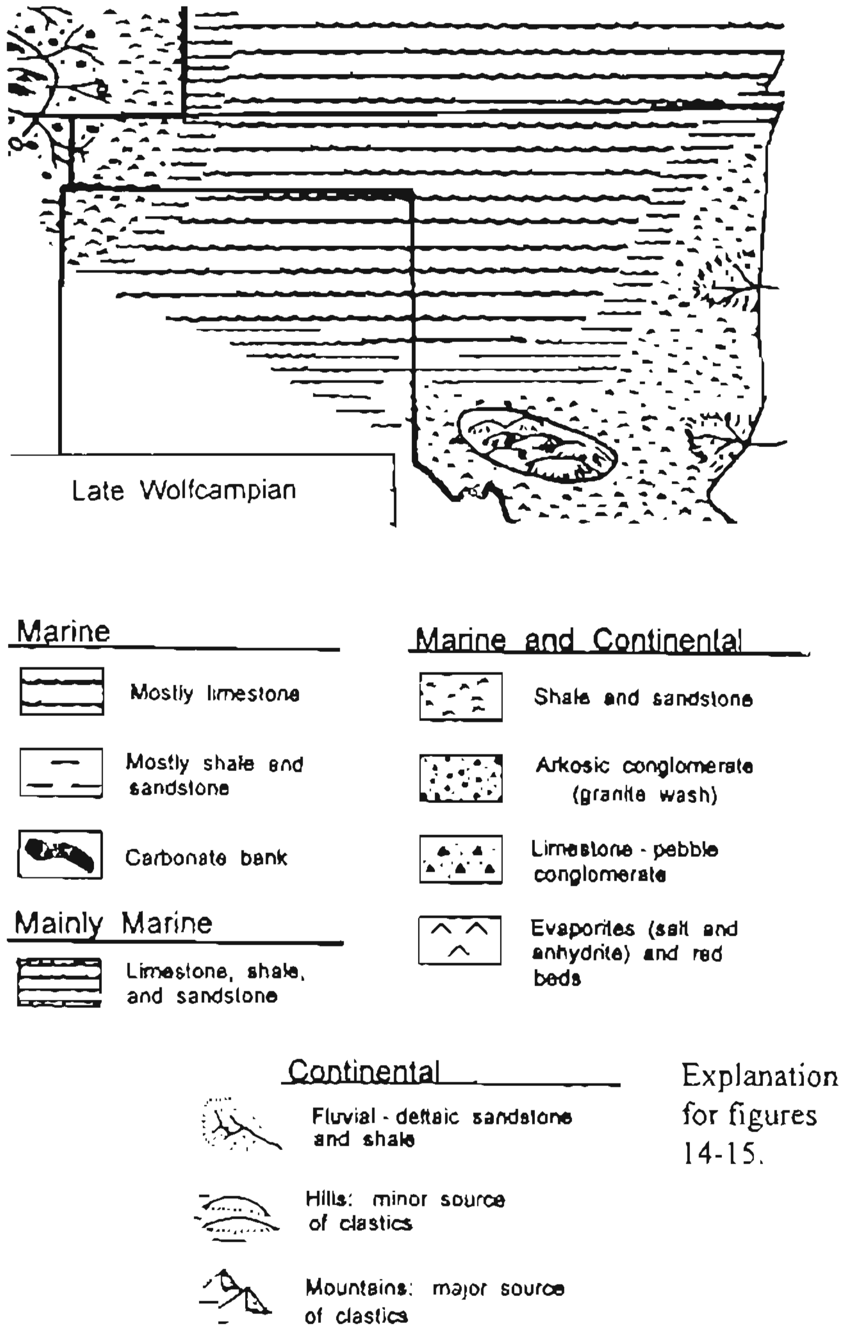


Figure 14. Generalized paleogeography and paleoenvironments of the Oklahoma region during Late Wolfcampian (modified from Johnson and others, 1988).

Leonardian Stage

Leonardian time was marked by continued slow subsidence of the Anadarko Basin and regression of the sea from the region. As a result, the dominant lithologies of the Leonardian Stage are red beds and evaporites deposited in continental and shallowing marine environments (Fig. 15) (Johnson and others, 1988, p. 325). The Amarillo-Wichita Uplift continued to have a modest influence on sedimentation in the Anadarko Basin, shedding clastic debris northward into the southern part of the basin.

Guadalupian Stage

In Guadalupian time the Anadarko Basin continued to subside. Sands entered the basin from the east, north and northwest and graded into shales and some salts toward the central and southwest parts of the basin (Fig 15) (Johnson and others, 1988, p 326) The Wichita Mountains had become buried, making the major sources for clastics deposited in the southern and eastern part of the basin areas of eastern Oklahoma and the deeply eroded Ouachita Foldbelt of southern Oklahoma and northeastern Texas (Johnson and others, 1988, p. 326).

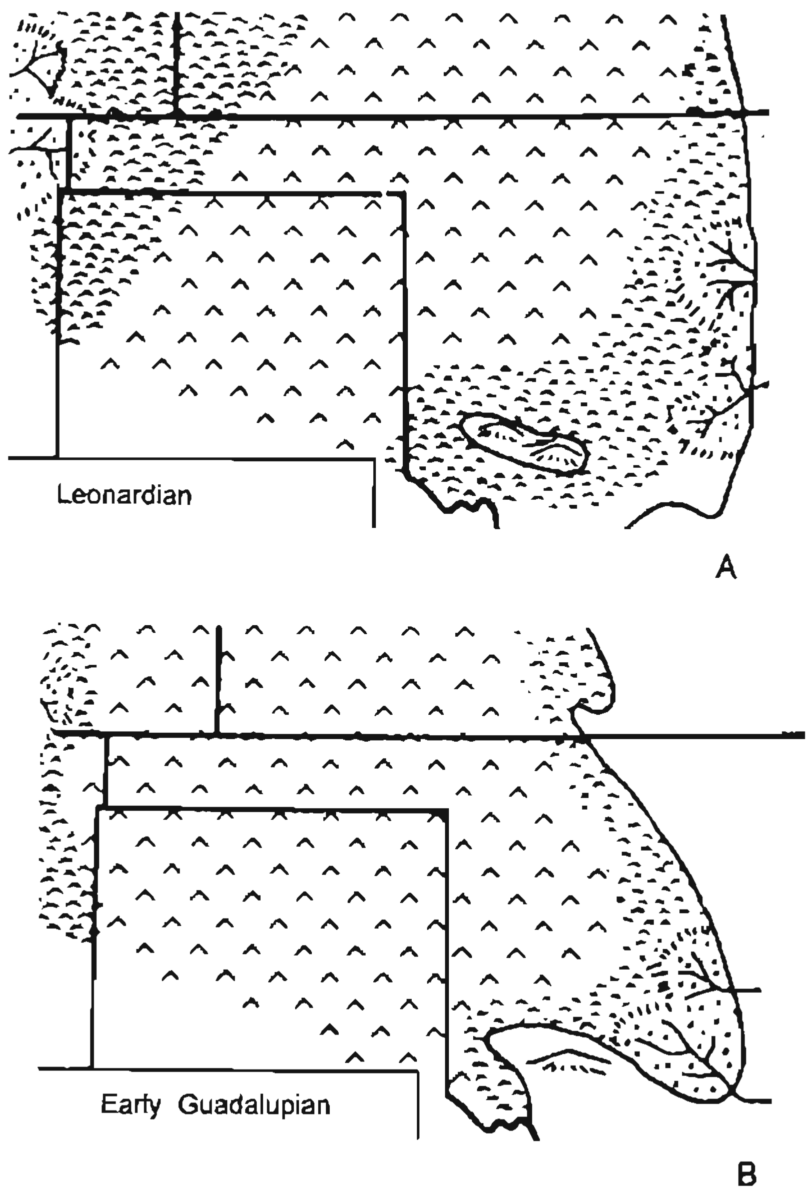


Figure 15. Generalized paleogeography and paleoenvironments of the Oklahoma region during (A) Leonardian time, (B) Early Guadalupian time (modified from Johnson and others, 1988).

CHAPTER III

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

The purpose of this chapter is to describe the stratigraphic intervals studied in the course of this research. The descriptions of the following sandstones are primarily from Jordan (1957).

Fortuna Sandstone

The Fortuna sandstone is in the Guadalupian Stage, Permian System. The Fortuna sandstone is the zone from the base of the Prosperity sandstone to the top of the Noble-Olson sandstone (Fig. 16). It is composed primarily of red shales with interbedded, thin, lenticular siltstones and fine-grained sandstones (Hermann, 1961, p. 1972).

The Fortuna sandstone was named in 1917, for the Fortuna Oil Company, Gregory No. 1, Sec. 31-T.6N.-R.9W., Cement Field, Caddo County, Oklahoma (Jordan, 1957, p. 69). The Fortuna sandstone is considered to be equal to the Ramsey sandstone of the Chickasha Field (Jordan, 1957, p. 69).

The Fortuna sandstone core examined in this study is from the Midcon Central Exploration Company, Elizabeth No. 10, Sec. 27-T.6N.-R.10W., Caddo County, Oklahoma (Fig. 17). The depositional environment was interpreted to be an alluvial environment, based on paleotectonic setting, geologic history, thin-section analyses

SYSTEM	SERIES	STAGE	GROUP	INFORMAL SUBSURFACE STRATIGRAPHIC NOMENCLATURE
PERMIAN	UPPER PERMIAN	GUADALUPIAN		RUSH SPRINGS MARLOW
			EL RENO	PROSPERITY FORTUNA
	LOWER PERMIAN	LEONARDIAN	ENID	NOBLE OLSON ss
		WOLFCAMPIAN	PONTOTOC	"BASAL PONTOTOC"

Figure 16. Informal subsurface stratigraphic nomenclature for the Fortuna sandstone (modified from Cipriani, 1963).

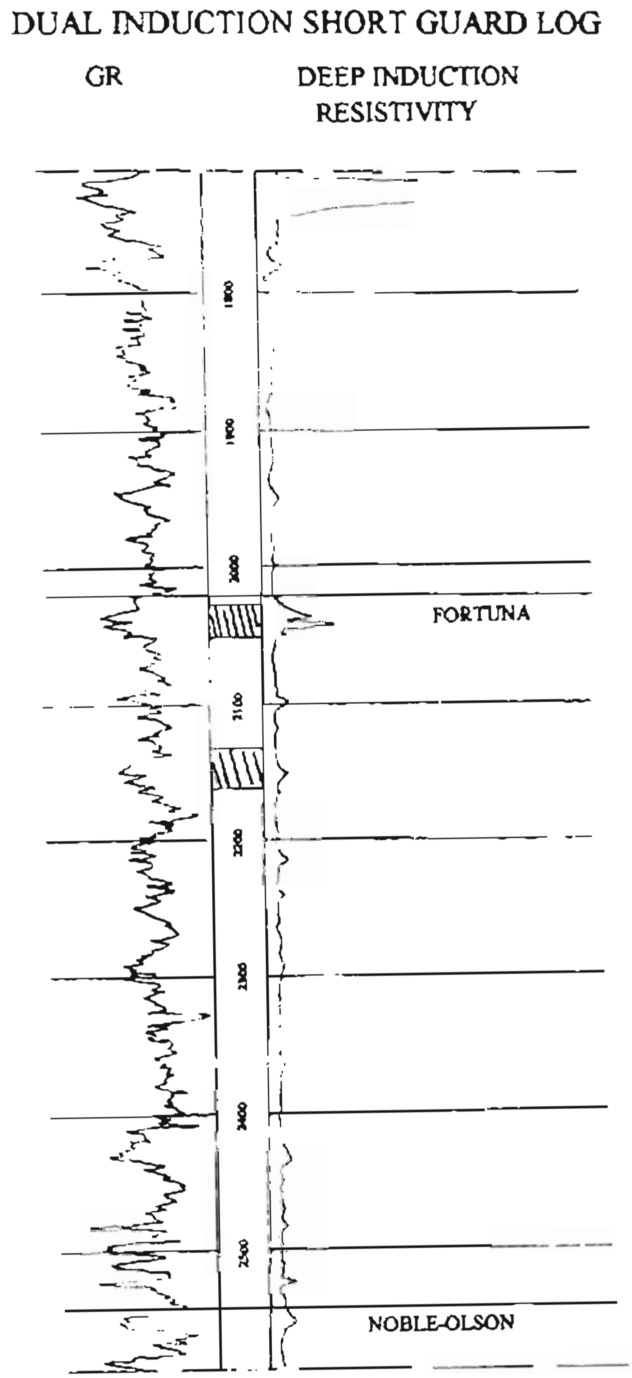


Figure 17. Log signature of the Fortuna sandstone in the Midcon Central, Elizabeth No. 10. Position of overlying Prosperity sandstone could not be determined.

(Appendix B p. 176) and core description (Appendix C p. 187-188). The information used to construct this conclusion is summarized in Appendix A p. 159-160.

Tonkawa Sandstone

The Tonkawa sandstone is in the lower part of the Douglas Group of the Virgilian Stage, Pennsylvanian sub-system. The Tonkawa sandstone is the zone from the base of the Lovell sandstone to the top of the Avant Limestone (Fig. 18) (Jordan, 1957, p. 192). It is composed of gray, fine- to medium-grained, moderately well sorted, micaceous, calcareous sandstone with subangular grains (Gibbons, 1965, p. 85). Kimberlin (1955, p. 8) described the Tonkawa sandstone as light-brown, fine-grained sandstone, calcareous at the base with thickness varying from 50 to 120 feet.

The Tonkawa sandstone was named after the Tonkawa Pool, T.24 and T.25N., R.1W., Kay County, Oklahoma (Jordan, 1957, p. 192). The Tonkawa is the stratigraphic equivalent of the Stalnaker sandstone of Kansas (Jordan, 1957, p. 192).

The Tonkawa sandstone depositional environment in parts of Dewey, Blaine, Custer, Caddo, and Canadian Counties, Oklahoma, (Fig. 19) was described by Kumar and Slatt (1984, p. 1839-1856). Kumar and Slatt used intervening shales to divide the Tonkawa into upper, middle and lower sandstones, and described the Tonkawa by evidence drawn from subsurface maps, cross-sections, core descriptions, thin-section analyses, and seismic stratigraphy. The lower Tonkawa sandstone was interpreted as a submarine fan complex. Kumar and Slatt based their interpretation on the following

SUB-SYSTEM	SERIES	STAGE	GROUP	INFORMAL SUBSURFACE STRATIGRAPHIC NOMENCLATURE
PENNSYLVANIAN	UPPER PENNSYLVANIAN	VIRGILIAN	WABAUNSEE	BROWNVILLE LS STONEBROKER ls BURLINGAME ls BIRD CREEK LS
			SHAWNEE	TOPEKA LS POWHUSKA ls DEER CREEK HOOVER ss ELGIN ss OREAD ls ENDICOTT ss
			DOUGLAS	LOVELL ls LOVELL ss **TONKAWA ss**
		MISSOURIAN	OCHELATA	AVANT LS COTTAGE GROVE SS DEWEY LS
			SKIATOOK	HOGSHOOTER LS LAYTON ss CHECKERBOARD LS CLEVELAND ss

Figure 18. Informal subsurface stratigraphic nomenclature for the Tonkawa sandstone (modified from Cipriani, 1963).

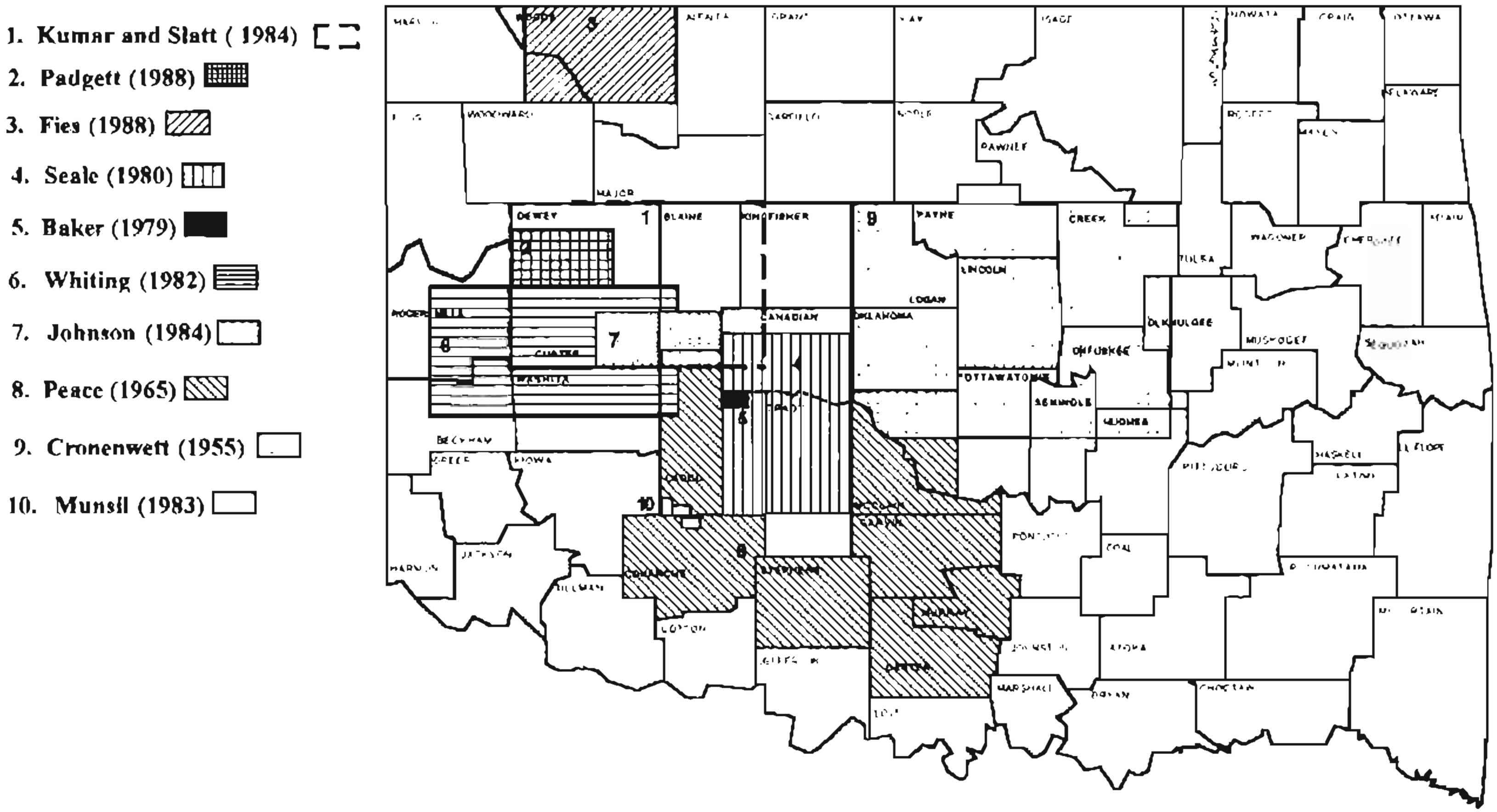


Figure 19. Study areas of previous works, listed by author.

evidence: (1) the regional setting indicates that the sandstone was deposited tens of miles from the shelf edge. (2) Graded beds, convolute laminae, and load casts indicate transportation of sediment by gravity flows. (3) The geometry of the sandstone indicates channelized flows that coalesced to form an overall fan-like geometry. The middle Tonkawa sandstone was interpreted as a basinal-slope sequence. This interpretation was based on the following evidence: (1) the regional setting indicated that the unit was located immediately basinward of the shelf edge and that it prograded over the lower Tonkawa sandstone. (2) Deposition of sediment in sheets or aprons was deduced from the lateral continuity of individual beds across several miles. (3) Small-scale cross-laminae, wavy and flaser bedding, and sharp bed contacts suggested bottom-current activity. The upper Tonkawa sandstone was not studied in detail by Kumar and Slatt, but from the regional setting and lithologic character they suggested a shallow-water (nearshore) deposition.

The Tonkawa sandstone depositional environment in part of Dewey County, Oklahoma, (Fig 19) was described by Padgett (1988, p. 42-49). Padgett investigated the Tonkawa sandstone using cross-sections, subsurface maps, core descriptions and thin-section analyses. His interpretation of a deltaic depositional environment was based on the following evidence: (1) Coarsening-upward sandstone bodies in gradational contact with interstratified sandstone-and-shale sequences, the sandstones of which were interpreted as distributary-mouth bars. (2) The sandstones were thin (3) The funnel-shaped well log patterns suggested that deposition occurred in a deltaic environment.

The Tonkawa sandstone depositional environment in parts of Harper and Woods Counties, Oklahoma, (Fig. 19) was described by Fies (1988, p. 32-50). Fies interpreted the depositional environment as fluvial and deltaic basing his interpretation on subsurface maps. core descriptions, and thin-section analyses.

The Tonkawa sandstone core examined in this study is from the Lear Petroleum, McGlone No. 1-35, Sec. 35-T.11N.-R.13W., Caddo County, Oklahoma (Fig. 20). The depositional environment was interpreted as having been a shallow marine shelf environment, based on paleotectonic setting, geologic history, thin-section analyses (Appendix B p. 177), and core description (Appendix C p. 189). The evidence used to construct this conclusion is summarized in Appendix A p. 161-162.

Marchand Sandstone

The Marchand sandstone is in the lower part of the Skiatook Group, Missourian Stage, Pennsylvanian sub-system. The Skiatook Group is defined as the interval from the top of the upper oolitic limestone to the base of the Culp Melton zone. The Marchand sandstone is defined as the zone from the base of the Medrano sandstone to the top of the Culp-Melton zone (Fig. 21) and is as much as 382 feet thick (Jordan, 1957, p. 128).

The Marchand sandstone was named for The Marchand Lease of Gorton Trust, NW Sec.2-T.5N.-R.9W., Cement Field, Caddo County, Oklahoma (Jordan, 1957, p. 128).

The Marchand sandstone depositional environment in parts of Caddo, Grady, and Canadian Counties, Oklahoma, (Fig. 19) was described by Seale (1980, p. 322-343).

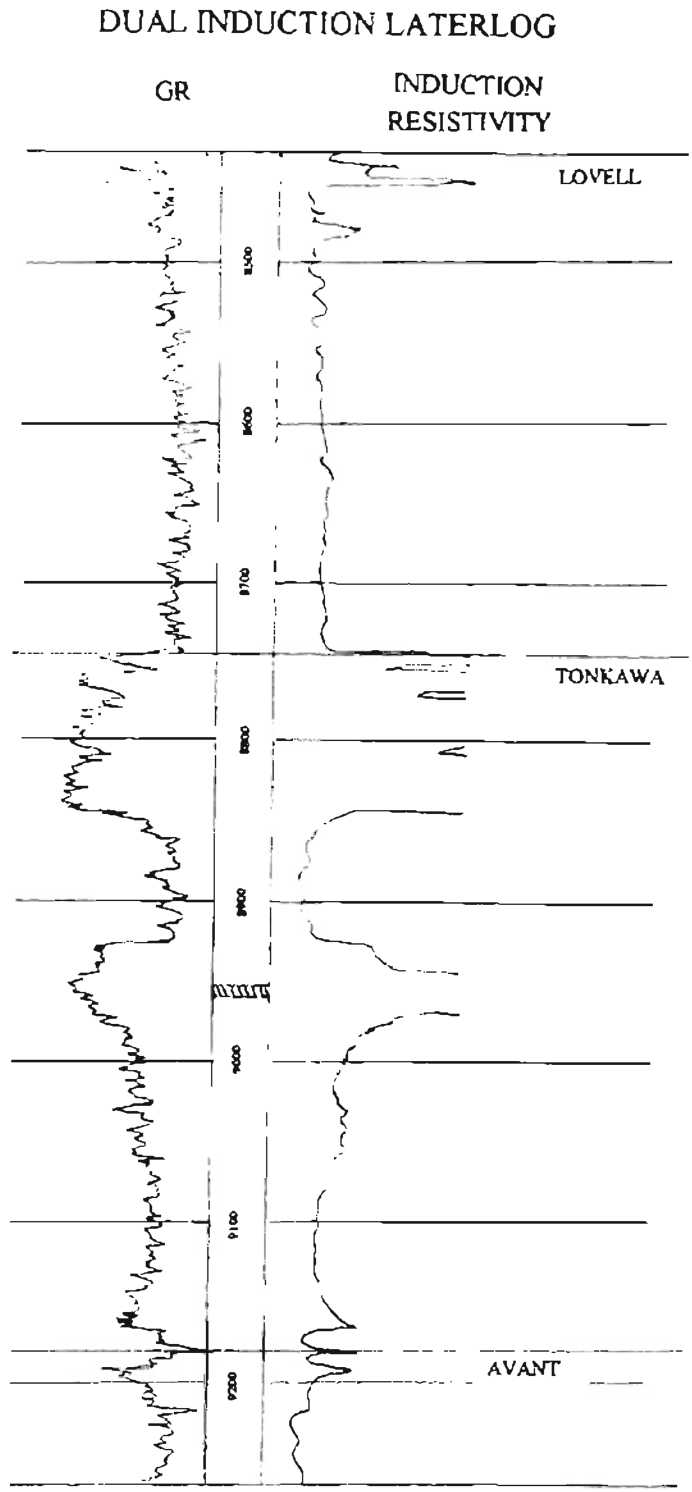


Figure 20. Log signature of the Tonkawa sandstone in the Lear Petroleum, McGlone No. 1-35. Bounding units are the Lovell sandstone and Avant Limestone.

SUB-SYSTEM	SERIES	STAGE	GROUP	INFORMAL SUBSURFACE STRATIGRAPHIC NOMENCLATURE
PENNSYLVANIAN	UPPER PENNSYLVANIAN	MISSOURIAN	OCHELATA	FIRST OOLITIC ls
				YULE (FUNK) ss
				BLACK OSTRACOD ls
				MAIN OOLITIC ls
			SKIATOOK	WADE ss
				BIG SHALE
				MEDRANO ss
				MARCHAND ss
				CULP ss
				MELTON ss
	MIDDLE PENNSYLVANIAN	DESMOINESIAN	MARMATON	U. GLOVER ss
				L. GLOVER ss

Figure 21. Informal subsurface stratigraphic nomenclature for the Marchand, Culp, and Melton sandstones (modified from Cipriani, 1963).

Seale interpreted the depositional environment as a marine-slope or ramp, based on evidence accumulated from cross-sections, subsurface maps, core descriptions and thin-section analyses. Evidence stated by Seale for a marine-slope ramp environment is as follows: (1) Abundant flowage features within the Marchand suggest an unstable slope during deposition or loading by the rapid introduction of material at the depositional site. (2) Sharp upper and lower contacts and uniform grain size in Marchand sandstones were evidence of rapid deposition. (3) Dip of interstratification and clay laminae was an indication of slope on the surface of deposition.

The Marchand sandstone depositional environment in the Binger Field of Caddo County, Oklahoma, (Fig. 19) was described as a shallow water tidal dominant environment by Baker (1979, p. 195-219). Baker's interpretation was based on information synthesized from both sandstone geometry and core examination (i.e., sedimentary structures, bedding, and vertical sequences).

The Marchand sandstone core examined in this study is from the Apexco Corporation, Walker No. 1, Sec. 8-T.11N.-R.12W., Caddo County, Oklahoma (Fig. 22). The depositional environment seems to have been a shallow marine shelf/slope environment, as based on information about paleotectonic setting and geologic history, and data from thin-section analyses (Appendix B p. 178), and core description (Appendix C p. 190-192). The evidence used to formulate this conclusion is summarized in Appendix A p. 163-164.

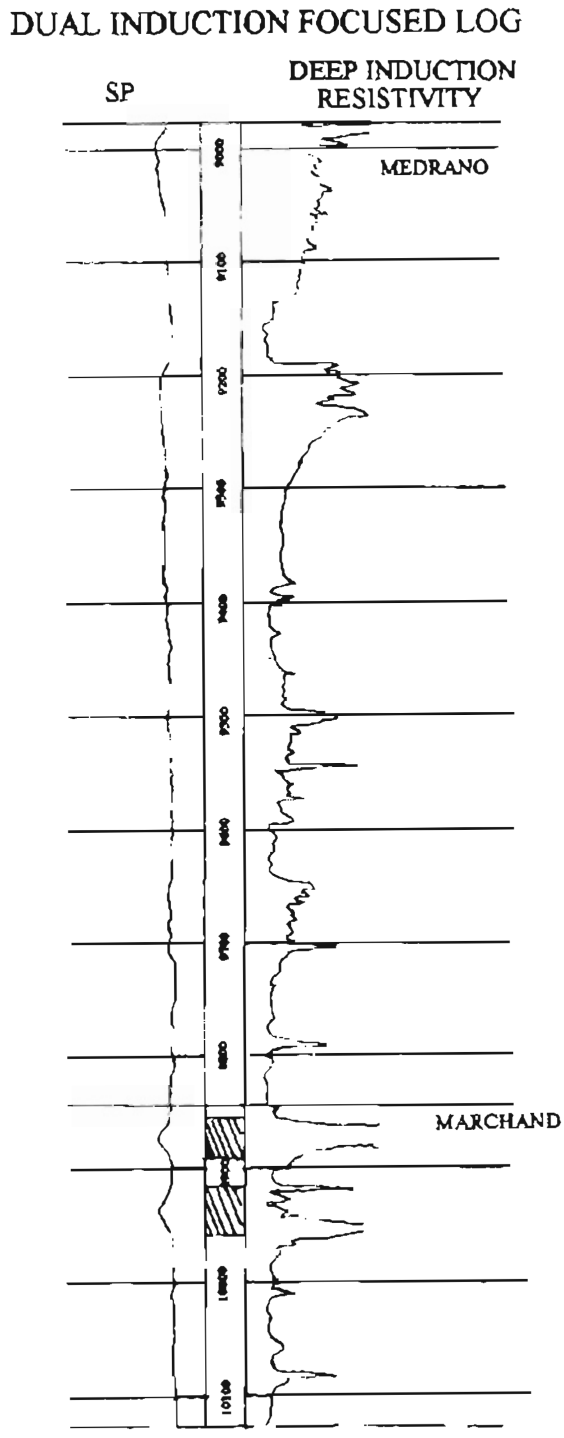


Figure 22. Log signature of the Marchand sandstone in the Apexco Corporation, Walker No. 1. Overlying unit is the Medrano. Well T.D. is in the Marchand sandstone.

Culp Sandstone

The Culp sandstone is located in the lower part of the Skiatook Group of the Missourian Stage, Pennsylvanian sub-system (Fig. 21). The Culp sandstone is the zone from the base of the Marchand sandstone to the top of the Melton zone (Jordan, 1957, p. 54).

The Culp sandstone was named for the Culp Lease of Mid-Kansas in well No. 6, Sec. 6-T.5N.-R.9W., Cement Field, Caddo County, Oklahoma (Jordan, 1957, p. 54).

The Culp sandstone core examined in this study is from the Lear Petroleum, Jones No. 1-26, Sec. 26-T.11N.-R.13W., Caddo County, Oklahoma (Fig. 23). The depositional environment is judged to have been a shallow marine to delta-margin environment, based on data concerning paleotectonic setting, geologic history, thin-section analyses (Appendix B p. 179), and core description (Appendix C p. 193). The evidence used to construct this conclusion is summarized in Appendix A p. 165-166.

Melton Sandstone

The Melton sandstone is in the lower part of the Skiatook Group of the Missourian Stage, Pennsylvanian sub-system. The Melton zone is from the base of the Culp sandstone to the top of the upper Glover sandstone (Fig. 21) (Jordan, 1957, p. 77, 133). The Melton sandstone is as much as 500 feet in thick and is composed of brown oolitic limestone, shale, and calcareous sandstone (Jordan, 1957, p. 133).

The Melton sandstone was named for the Melton Lease of Ray Stephens, Inc., Sec.26-T.6N.-R.10W., Cement Field, Caddo County, Oklahoma (Jordan, 1957, p. 133).

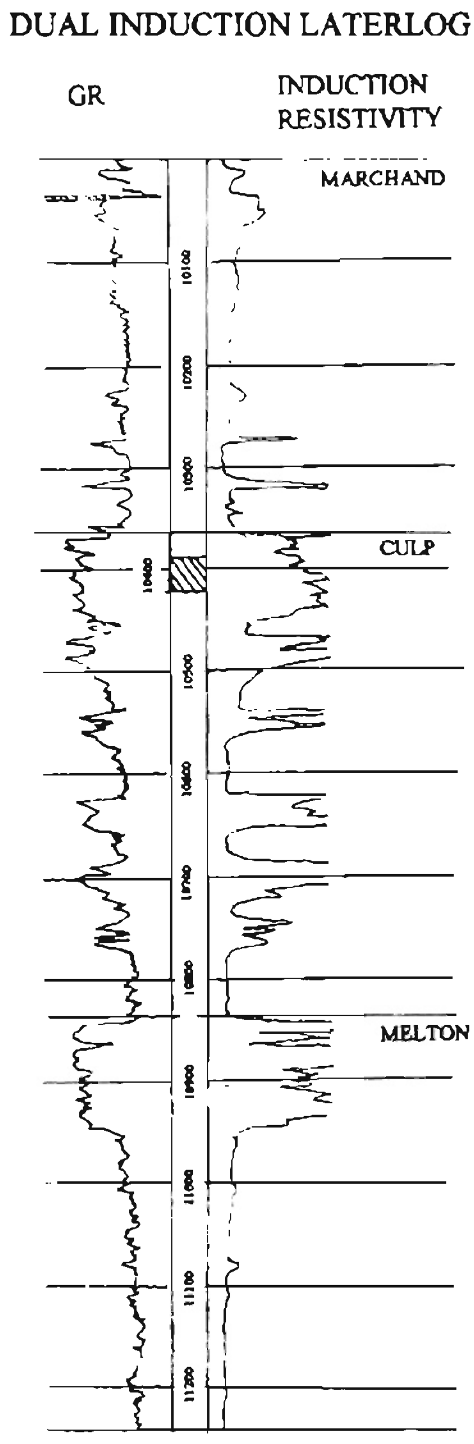


Figure 23. Log signature of the Culp sandstone in the Lear Petroleum, Jones No. 1-26. Bounding units are the Marchand and Melton sandstones.

The Melton sandstone core examined in this study is from the Lear Petroleum, McGlone No. 1-35, Sec. 35-T.11N.-R.13W., Caddo County, Oklahoma (Fig. 24). The depositional environment probably was a shallow marine slope environment, as indicated by paleotectonic setting, geologic history, thin-section analysis (Appendix B p. 180), and core description (Appendix C p. 194-195). The evidence used to formulate this conclusion is summarized in Appendix A p. 167-168.

Red Fork Sandstone

The Red Fork sandstone is in the middle of the Cherokee Group of the Desmoinesian Stage, Pennsylvanian sub-system. The Red Fork sandstone is from the base of the Pink limestone to the top of the Inola Limestone (Fig. 25) (Jordan, 1957, p. 165). In most localities it is composed of lenticular sandstone beds separated by sandy and silty shales (Jordan, 1957, p. 165).

The Red Fork sandstone was named for the Red Fork Field, Creek and Tulsa Counties, Oklahoma (Jordan, 1957, p. 165). The Red Fork is equal to the Taft Sandstone in outcrop (Jordan, 1957, p.165).

The Red Fork sandstone depositional environment in parts of Roger Mills, Custer, Blaine, Caddo, Beckham, and Washita Counties, Oklahoma, (Fig. 19), was described by Whiting (1982, p. 104-119). Whiting interpreted the Red Fork sandstone's depositional environment as deep marine based on cross-sections, subsurface maps, core descriptions and thin-section analyses. The following is the evidence stated by Whiting: (1) the sandstones form repetitive, ordered sequences of sedimentary structures characteristic of

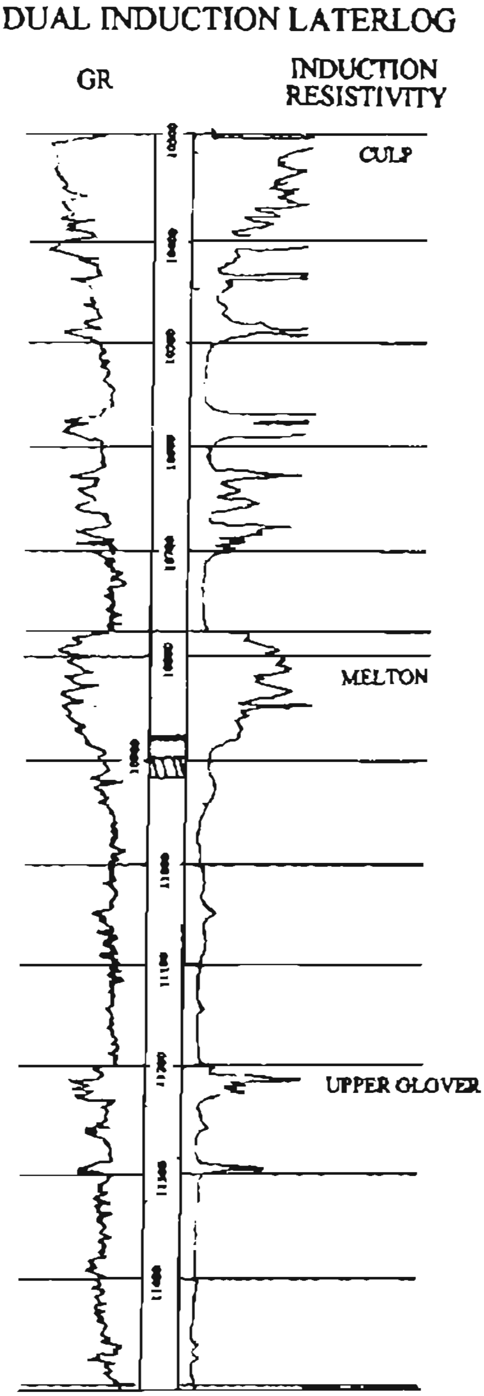


Figure 24. Log signature of the Melton sandstone in the Lear Petroleum, McGlone No. 1-35. Bounding units are the Culp and upper Glover sandstones.

SUB-SYSTEM	SERIES	STAGE	GROUP	INFORMAL SUBSURFACE STRATIGRAPHIC NOMENCLATURE
PENNSYLVANIAN	MIDDLE PENNSYLVANIAN	DESMOINESIAN	MARMATON	BIG ls
				OSWEGO ls
			CHEROKEE	"CHEROKEE" HOT SHALE
				PRUE ss
				VERDIGRIS LS
				SKINNER ss
				PINK ls
				RED FORK ss
				INOLA LS
				BARTLESVILLE ss
				BURGESS ss
				UNCONFORMITY ss

Figure 25. Informal subsurface stratigraphic nomenclature for the Red Fork sandstone (modified from Cipriani, 1963).

turbidite deposition. (2) Individual bedding sequences display decrease in grain size and quartz content upward and increase in matrix content upward. (3) Other features of the sandstone which indicate turbidite deposition include sharp basal contacts with basal shale clasts, extremely contorted bedding, and gradational tops.

The Red Fork sandstone depositional environment in parts of Dewey, Blaine, and Caddo Counties, Oklahoma, (Fig. 19) was described by Johnson (1984, p. 40-61) separating the Red Fork into upper and lower units. Johnson interpreted the lower Red Fork sandstone as a shelf-slope depositional environment and the upper Red Fork sandstone as a deltaic complex. Johnson based his interpretations on examinations of subsurface maps, cross-sections, core analyses and petrographic thin-section studies.

The Red Fork sandstone core examined in this study is from the Hunt Energy Corporation, Gillingham No 1, Sec. 21-T.9N.-R.12.W, Caddo County, Oklahoma (Fig. 26). The depositional environment was interpreted to be a submarine fan to basin-floor environment, based on paleotectonic setting, geologic history, thin-section analyses (Appendix B p. 181-182), and core description (Appendix C p. 196-197). The evidence used to construct this conclusion is summarized in Appendix A p. 169-170.

Springer Sandstone

The Springer sandstone is in the Chesterian Stage, Mississippian sub-system. The Springer zone is from the base of the Primrose sandstone to the top of the Goddard Shale (Fig. 27) (Jordan, 1957, p. 184). The Springer ranges from 100-200 feet in

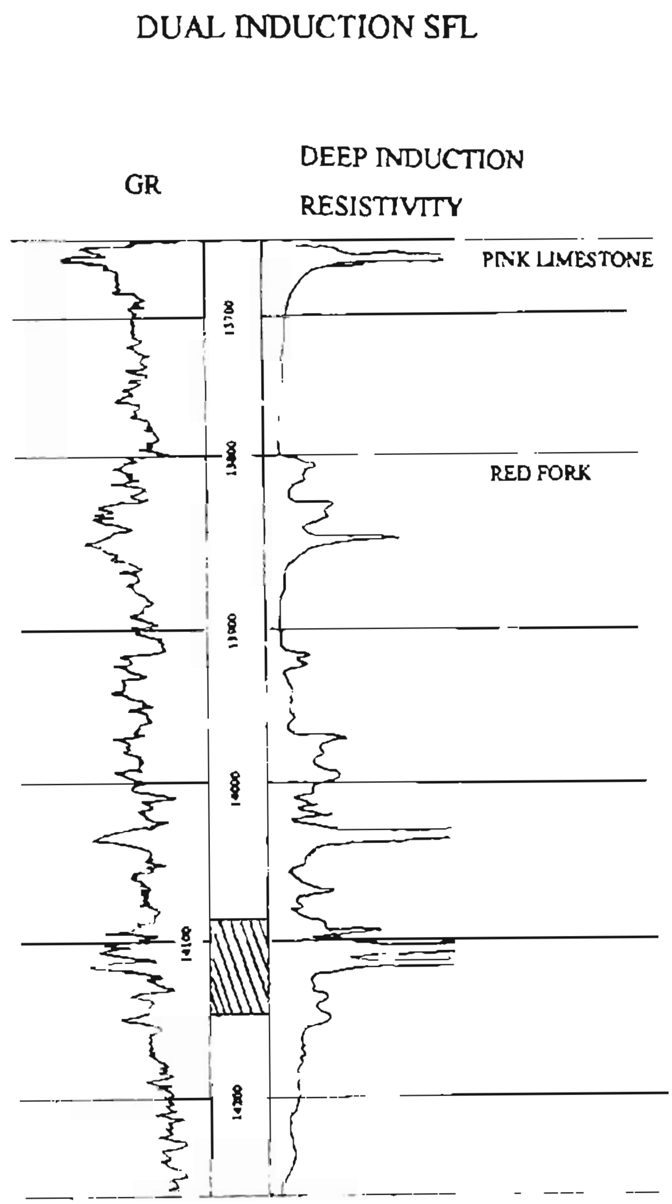


Figure 26. Log signature of the Red Fork sandstone in the Hunt Energy Corporation, Gillingham No. 1. Overlying unit is the Pink limestone. Well T.D. is in the Red Fork sandstone.

SUB-SYSTEM	SERIES	STAGE	GROUP	INFORMAL SUBSURFACE STRATIGRAPHIC NOMENCLATURE
PENNSYLVANIAN	LOWER PENNSYLVANIAN	MORROWAN	LOWER DORNICK HILLS	LOWER DORNICK HILL sh
				PRIMROSE LS
				PRIMROSE SS
MISSISSIPPIAN	UPPER MISSISSIPPIAN	CHESTERIAN	SPRINGER	CUNNINGHAM ss
				BRITT ss
				GODDARD SH
				CANEY SH

Figure 27. Informal subsurface stratigraphic nomenclature for the Springer sandstone (modified from Cipriani, 1963).

thickness and is composed of fine-textured clay shales interbedded with light-gray, glassy, fine-grained, quartzitic sandstones (Gibbons, 1965, p. 73).

The Springer was named for the town of Springer, Carter County, Oklahoma (Jordan, 1957, p. 184).

The Springer sandstone in parts of Caddo, Comanche, McClain, Stephens, Garvin, Carter, and Murray Counties, Oklahoma, (Fig. 19) was studied by Peace (1965, p. 81-97). Peace interpreted a shelf or platform environment of deposition based on geologic history, subsurface maps, and petrologic descriptions.

The Springer sandstone core examined in this study is from the Mustang Production Company, Crawford No. 31, Sec. 31-T.15N.-R.12W., Blaine County, Oklahoma (Fig. 28). The depositional environment for this sandstone was interpreted to be a shallow marine shelf environment, based on paleotectonic setting, geologic history, thin-section analyses (Appendix B p. 183), and core description (Appendix C p. 198). The evidence used to formulate this conclusion is summarized in Appendix A p. 171-172.

<u>Bromide Sandstone</u>

The Bromide sandstone is in the upper part of the Simpson Group of the Champlainian Stage, Ordovician System. The Simpson Group is composed of alternating massive sandstones, thin-bedded shales and limestones (Cronenwett, 1955, p. 171). According to Statler (1965), the Simpson sandstones are composed of subangular to well-rounded grains which commonly display pitted surfaces and/or secondary silica

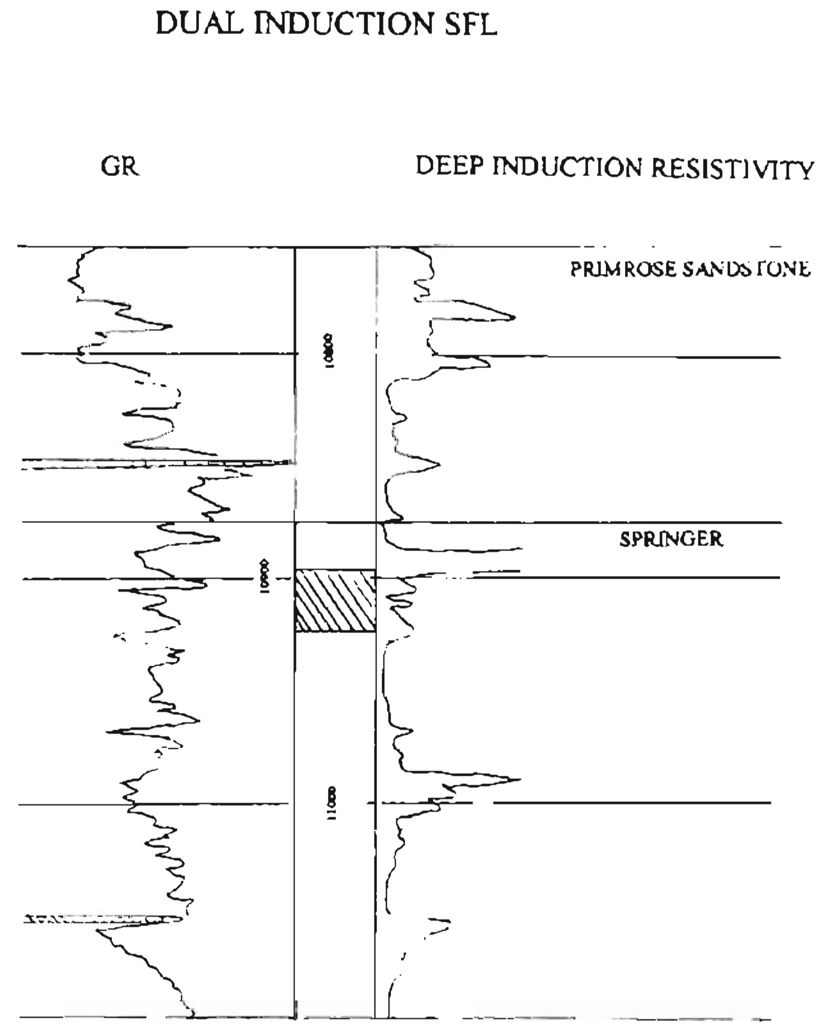


Figure 28. Log signature of the Springer sandstone in the Mustang Production Company, Crawford No. 31. Overlying unit is the Primrose Sandstone. Well T.D. is in the Springer.

overgrowths. The sands may be friable and cement-free, or tightly cemented with carbonate or silica cements.

The Bromide is described as the zone from the base of the Viola Springs Formation to the top of the Tulip Creek Formation (Fig. 29) (Cronenwett, 1955, p. 172). The Bromide is as much as 340 feet in thickness (Cronenwett, 1955, p. 184) and is composed of light-tan to white, medium-grained, subangular, tight sandstone with dolomitic cement (Boekman, 1958, p. 107 and Wallace, 1954, p. 10).

The Bromide sandstone was named by Ulrich in 1911, from exposures near the former village of Bromide, Oklahoma (Cronenwett, 1955, p. 184). The Bromide is equal to the Wilcox sandstone (Cronenwett, 1955, p. 184), to the Platteville of Kansas, and the Plattin of Missouri and Illinois (Ireland, 1965, p. 75).

The Bromide sandstone depositional environment in parts of Logan, Payne, Creek, Oklahoma, Lincoln, Okfuskee, Olkmulgee, Pottawatomie, Seminole, Hughes, and McClain Counties, Oklahoma, (Fig. 19) was described as a platform environment by Cronenwett (1955, p. 184-186). Cronenwett based his interpretation on cross-sections, rotary-drilling sample descriptions and electric log analyses.

The Bromide sandstone depositional environment in parts of Caddo and Comanche Counties, Oklahoma, (Fig. 19) was described by Munsil (1983, p. 149-154) as shallow-water marine deposition. Munsil based his interpretation on geologic setting, core analyses, and petrographic thin-section analyses.

The Bromide sandstone core examined in this study is from the Mustang

SYSTEM	SERIES	STAGE	GROUP	INFORMAL SUBSURFACE STRATIGRAPHIC NOMENCLATURE	
ORDOVICIAN	MIDDLE ORDOVICIAN	CHAMPLAINIAN	VIOLA	WELLING	
				VIOLA SPRINGS	
			SIMPSON	BROMIDE	BROMIDE DENSE
					FIRST BROMIDE
					SECOND BROMIDE
				TULIP CREEK (THIRD BROMIDE)	
				McLISH	
				OIL CREEK	
				JOINS	

Figure 29. Informal subsurface stratigraphic nomenclature for the Bromide sandstone (modified from Amsden and Sweet, 1983).

Production Company, Barnes No. 1-25, Sec. 25-T.9N.-R.7W., Grady County, Oklahoma (Fig. 30). The depositional environment of this sandstone was interpreted to be a shallow marine platform environment, based on paleotectonic setting, geologic history, and thin-section analyses (Appendix B p. 184), and core description (Appendix C p. 199-200). The evidence used to construct this conclusion is summarized in Appendix A p. 173-174.

Figure 31 is a stratigraphic column of the Anadarko Basin modified after Johnson and others (1988) showing the range of stratigraphic intervals studied in this project.

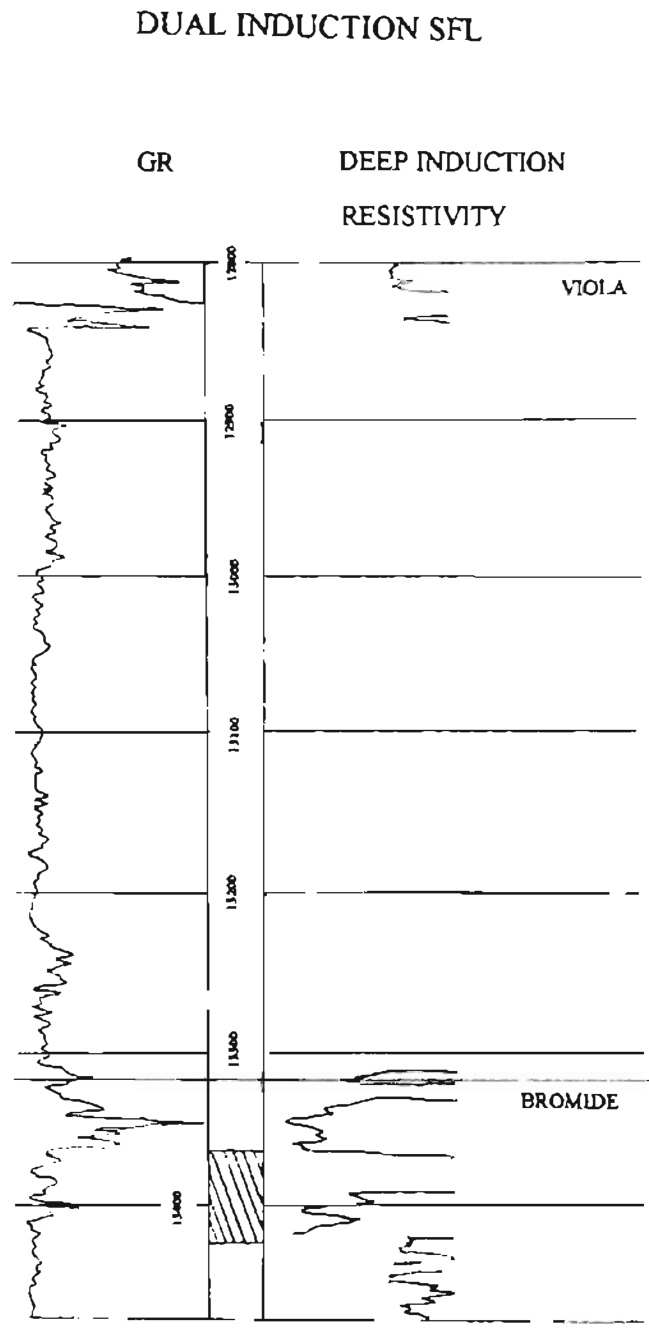


Figure 30. Log signature of the Bromide sandstone in the Mustang Production Company, Barnes No. 1-25. Overlying unit is the Viola. Well T.D. is in the Bromide.

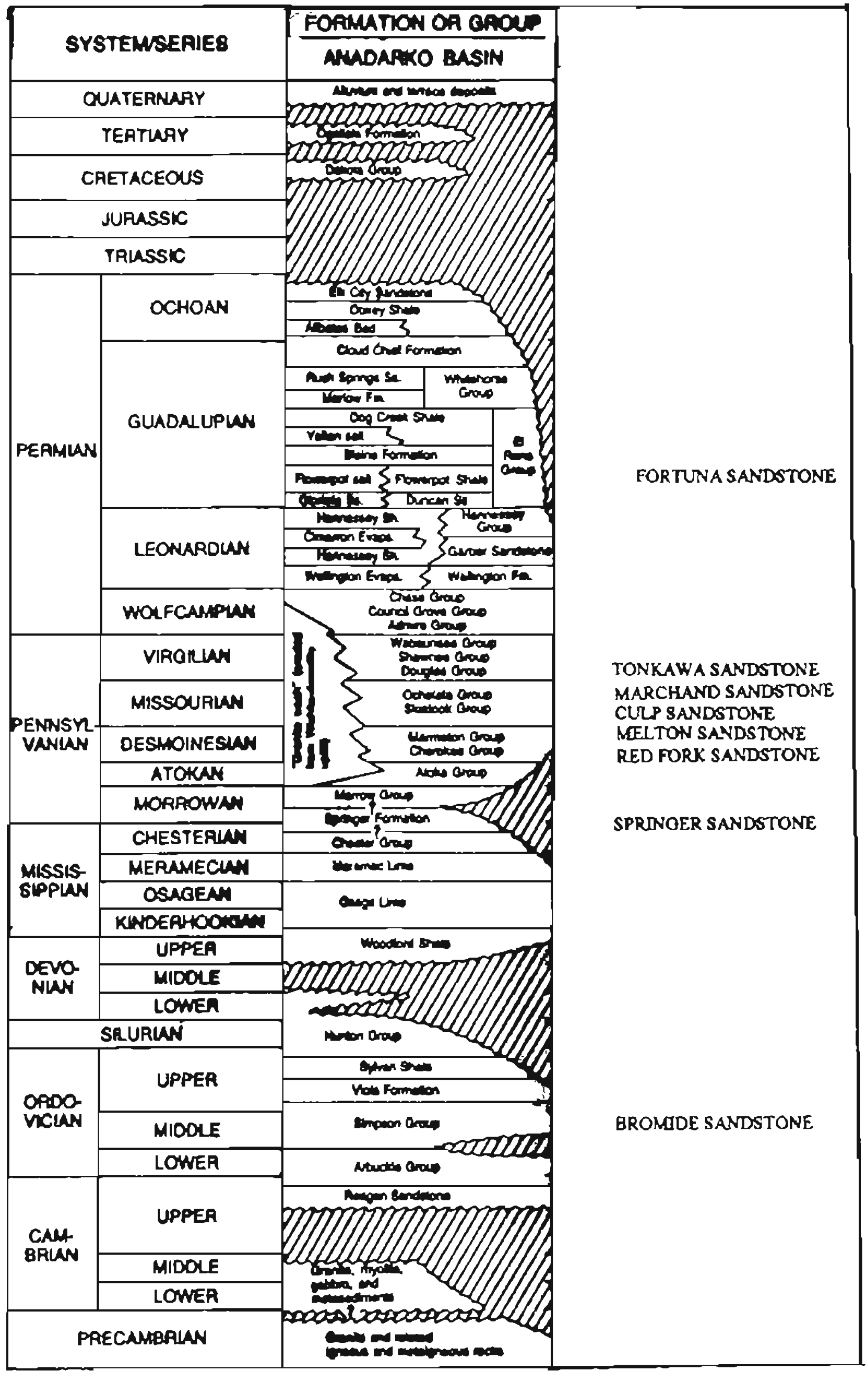


Figure 31. Stratigraphic column for the Anadarko Basin (modified from Johnson and others, 1988).

CHAPTER IV

PRESSURE COMPARTMENTS AND IDENTIFICATION OF SEALS

Previous Investigations

Abnormal Pressures

Early literature concerning abnormally high pressures is based mostly upon data from the Texas and Louisiana Gulf Coast region. As drilling increased in the Gulf of Mexico, the need to understand and recognize overpressured zones and the transitions into these zones became increasingly important. Canon and Craze (1938) were the first to discuss abnormal pressures in the Gulf Coast area of Texas and Louisiana. They studied reservoir pressures by relating the reservoir pressure with depth below sea level. MacGregor (1965) used conductivity curves of induction-electrical logs to define the depths at which boreholes entered abnormally pressured zones. Powers (1967) suggested that clay diagenesis might be the cause for high pressures. Myers (1968) dealt with the relationship between subsurface pressure changes and the entrapment of hydrocarbons by faults. Baker (1972) suggested aquathermal pressuring, the thermal expansion of fluids, as a possible mechanism for generating abnormal subsurface pressures. Chapman (1972) analyzed the mechanical aspects of the compaction of clays to explain overpressuring in Gulf Coast sediments.

Pressure Seals and Compartments

Dickinson (1953) recognized an abrupt increase in pressure above normal hydrostatic pressure that occurred over a short vertical interval in Gulf Coast sediments. Chiarelli and Duffaud (1980) documented the concept of pressure "compartments" in the Jurassic strata of the Viking Basin in the North Sea. Chiarelli and Duffaud defined a series of compartments in the basin as bodies of rock with their own distinct hydrodynamic environments. Bradley (1975) recognized that for abnormal pressures to exist there must be an effective seal. Without a seal, the abnormally pressured reservoirs would equalize with the hydrostatic pressure gradient. Powley (1987) studied 180 basins worldwide and documented general characteristics of pressure seals within these basins. Hunt (1990) studied the process of episodic dewatering from overpressured fluid compartments due to fracturing of seals. Downey (1984) evaluated various seals for hydrocarbon trapping mechanisms.

Hydraulic Systems

Most deep sedimentary basins in the world consist of a layered arrangement of at least two hydraulic systems (Powley, 1987, p. 1). The first system, which is hydraulically connected to the surface (Dahlberg, 1982, p. 82) and basin-wide in extent, contains normal (hydrostatic) pressure gradients (Powley, 1987, p. 7). Normal (hydrostatic) pressure gradients are 0.465 pounds per square inch per foot for "standard" water containing 100 parts per thousand of total dissolved solids (North, 1985). The second system is deeper, without surface connection, and is not basin-wide in extent. It contains abnormal pressures either less than hydrostatic gradients (underpressured) or greater than hydrostatic gradients (overpressured) (Fig. 32) (Powley, 1987, p.1). In some basins, mainly onshore in the United States, a third abnormally hydraulic system is present. The third system is deeper than the abnormally pressured system forming a three-layer hydraulic system. This system is basin-wide in extent and contains normal (hydrostatic) pressure gradients (Fig. 33) (Powley, 1987, p. 1). Figure 34 is a pressure depth profile exemplary of the three hydraulic systems, showing the location of the overpressured middle system and the normally pressured systems above and below.

The Anadarko Basin in Oklahoma is one example of a basin containing three hydraulic systems. In the Anadarko Basin, the second (middle) system is composed of overpressured compartments. These compartments are a two-component subsystem consisting of porous and permeable rock surrounded by a seal. Pressure compartments are characterized by a seal that prevents interior pressure equalizing to normal (hydrostatic) pressure (Fig. 35) (Bradley and Powley, 1994, p. 3). Al-Shaieb (1991, p. 52) introduced the term *megacompartment complex* (MCC) for the basin-wide, overpressured, completely sealed compartment in the Anadarko Basin.

Pressure Seals

'A pressure seal restricts flow of both hydrocarbon and brine and is formed where the pore throats become effectively closed, i.e., the permeability approaches zero' (Bradley and Powley, 1994, p. 8).

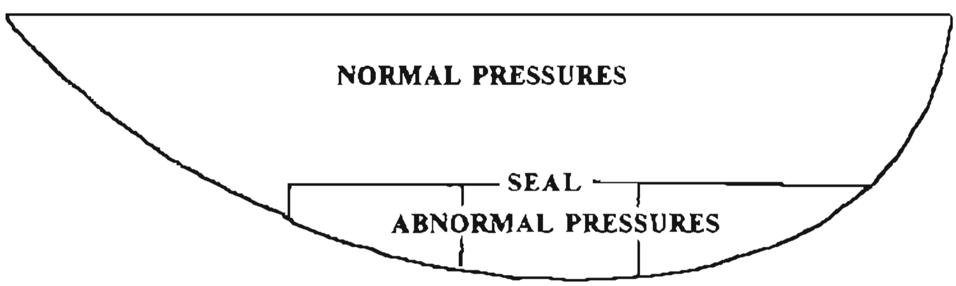


Figure 32. Basinal layered arrangement of two superimposed hydraulic systems (modified from Powley, 1987)

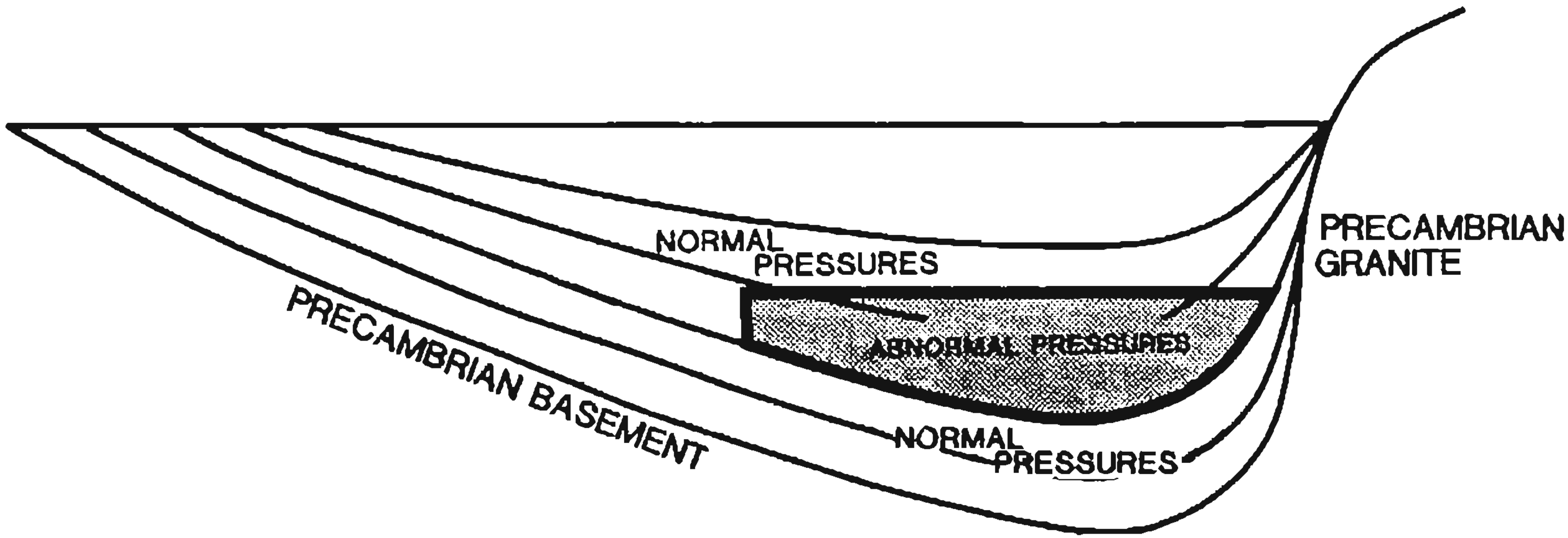


Figure 33. Basinal layered arrangement of three hydraulic systems (from Powley, 1987).

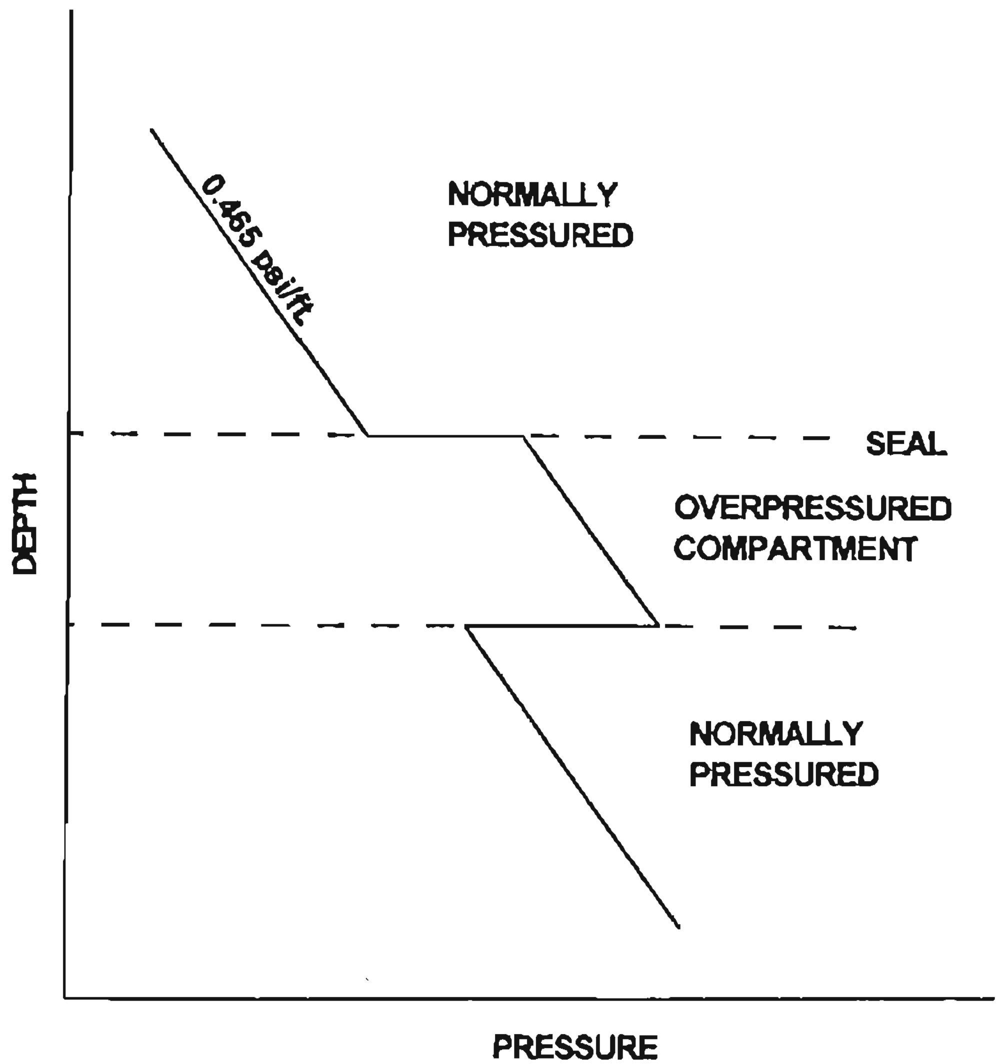


Figure 34. Pressure-depth profile showing an incremental increase in pressure, which indicates the overpressured compartment and the location of the top and basal seals.

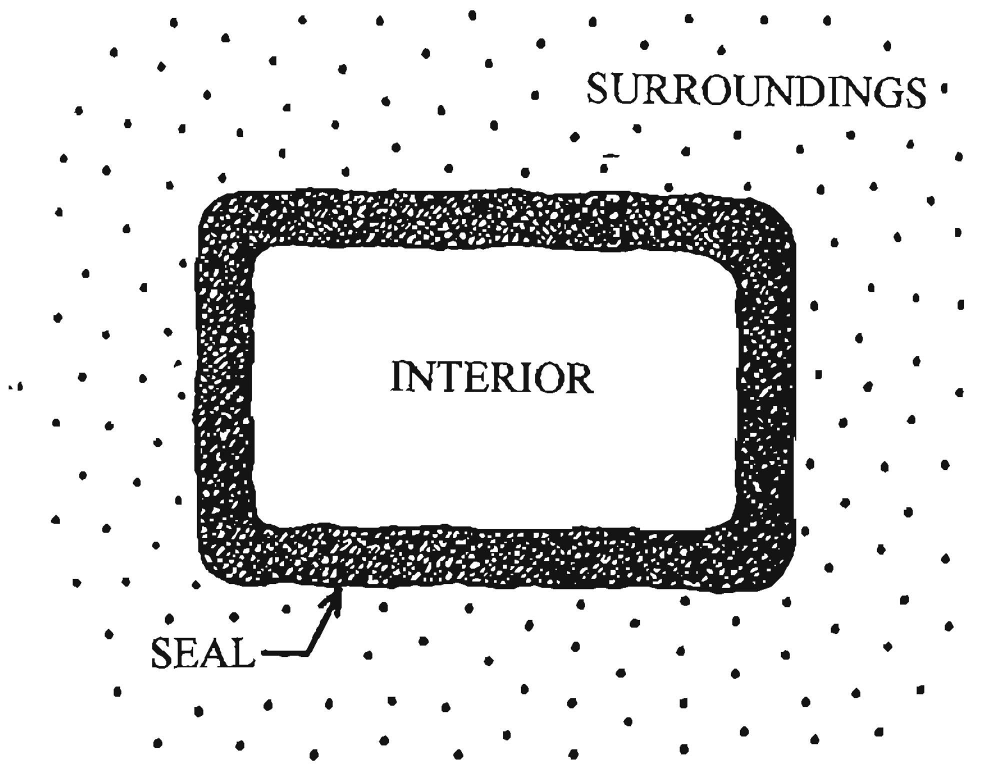


Figure 35. Generic compartment showing an interior of good hydraulic connectivity separated from its surroundings by a low permeability seal (from Ortoleva, Al-Shaieb, and Puckette, 1995).

Pressure seals develop in bodies of rock within the deep-basin environment. In the Anadarko Basin, the pressure seals contain diagenetic banding structures (Al-Shaieb and others, 1994, p. 351), which are important in the isolation of high-pressure areas Diagenetic banding is in rocks buried deep enough to enter the "seal window" (6000-10,000 ft.) and are not in rocks of shallower intervals (Al-Shaieb and others, 1994, p 66) Within the seal window, mechano-chemical processes form diagenetic seals through pressure solution and cementation Mechano-chemical processes that occur in sandstones for the formation of diagenetic seals include (1) clay-coating mediated feedback where clay coatings inhibit precipitation; (2) porosity feedback where higher grain stresses increase silica dissolution in more porous rock and induce silica precipitation into adjacent lower porosity areas; and (3) contact area feedback where silica dissolution is slower at larger grain-to-grain contacts than smaller grain contacts of similar volume (Ortoleva et al., 1995, p. 375-376)

Compartment-classification Schemes

The information in this section was originated by Al-Shaieb (1991) and Al-Shaieb and others (1993).

The megacompartment complex (MCC) in the Anadarko Basin is made of individual pressure compartments combined. These compartments within the mega-compartment complex are identified on the basis of pressure regimes A compartment-classification scheme was formed by Al-Shaieb and others (1993) based on size, stratigraphy, and pressures

Level 1

Level one compartment is a basin-wide, overpressured volume called the megacompartment complex (MCC) (Fig. 36). This complex is enclosed by top, basal and lateral pressure seals (Fig 37). The top seal transects stratigraphy and is at depths ranging from 7,500 to 10,000 feet (Al-Shaieb, 1991, p. 55). The basal seal follows stratigraphy and is believed to be the Woodford Shale (Al-Shaieb, 1991, p. 55). On the margin of the Wichita frontal fault zone, the megacompartment complex is bounded by a lateral seal (Al-Shaieb, 1991, p. 55). The megacompartment complex is approximately 150 miles long (northwest to southeast) and 70 miles wide (northeast to southwest) and is at least 16,000 feet thick (Al-Shaieb and others, 1993, p. 69) The megacompartment complex contains all rock sequences from the top seal in the Upper Pennsylvanian to the basal seal at the Woodford Shale (Fig. 38) Reservoirs within the megacompartment complex are overpressured containing a wide range of pressure gradients (from slightly to extremely overpressured) Figures 39, 40, and 41 are pressure-depth profiles that illustrate the overpressured megacompartment complex in the three counties of the study area The Fortuna, Tonkawa, Marchand, Culp and Melton sandstones are normally pressured above the megacompartment complex The Red Fork and Springer sandstones are overpressured within the megacompartment complex The Bromide sandstone is normally pressured below the megacompartment complex.

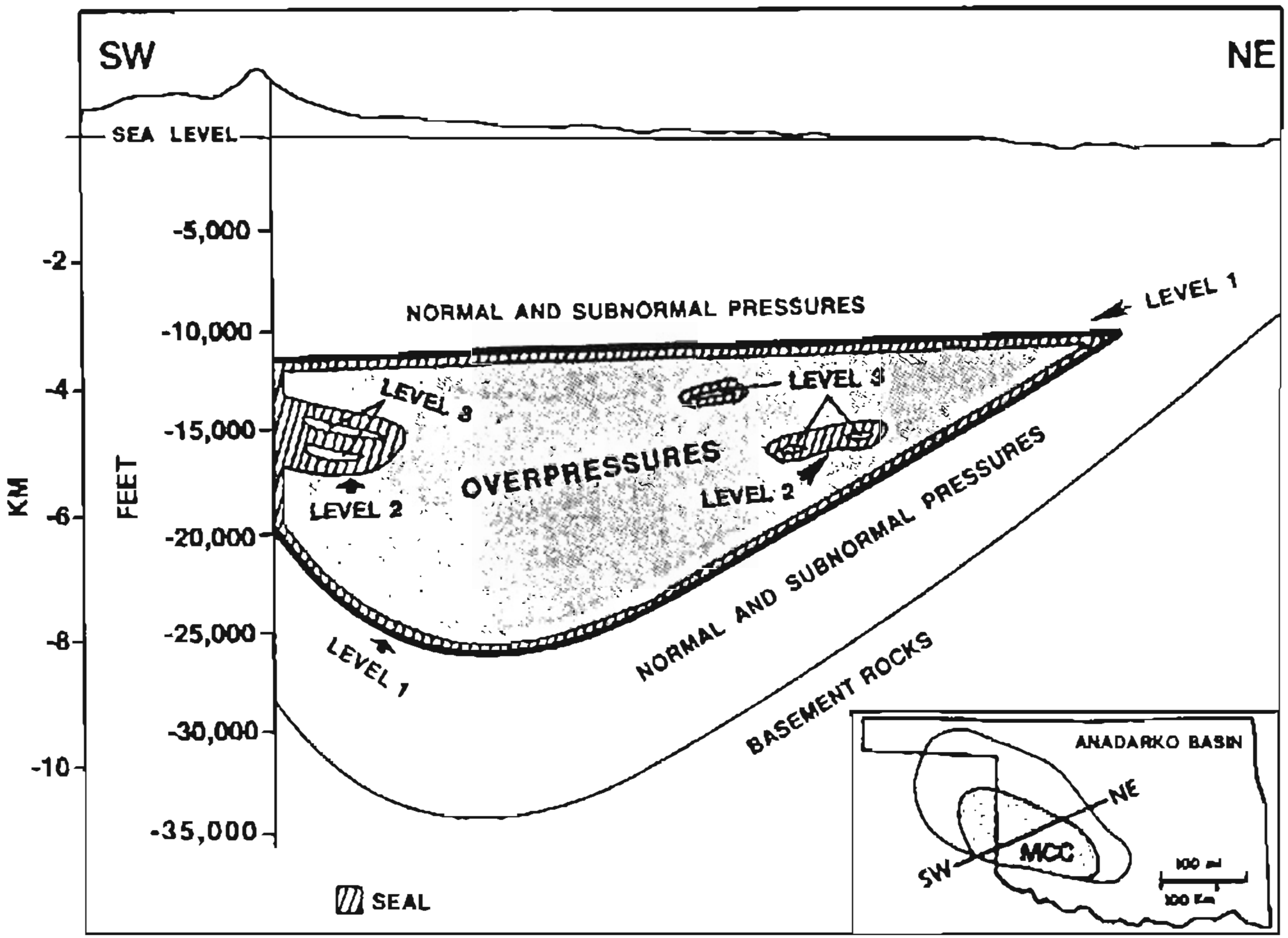


Figure 36. Schematic diagram illustrating the spatial relationship of the three levels of compartmentation in the Anadarko Basin. Inset map shows the areal extent of the Megacompartment Complex within the basin (from Al-Shaieb and others, 1993).

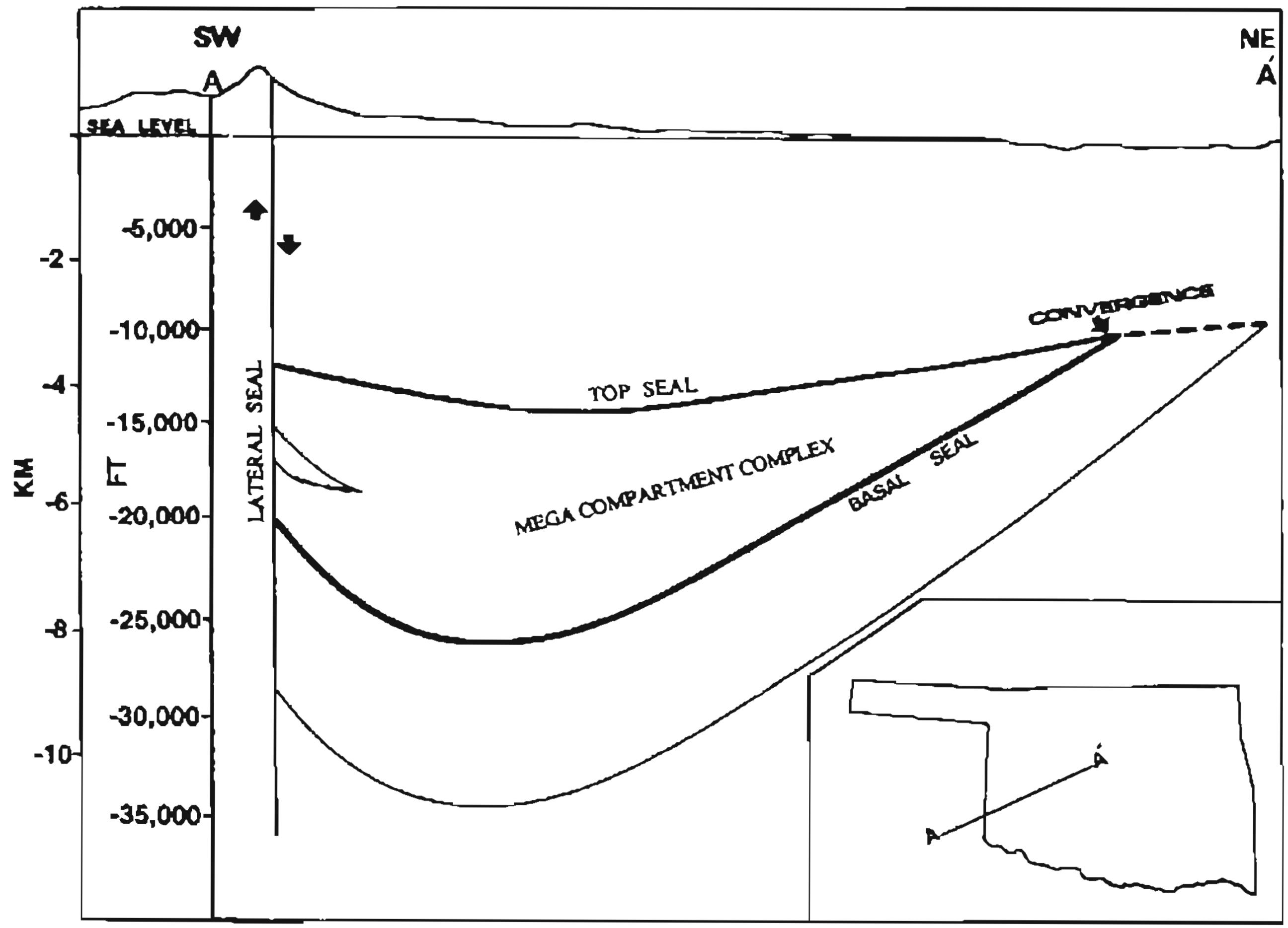


Figure 37. Generalized cross-section of the Anadarko Basin showing the spatial relationship of the Megacompartment Complex within the basin and the location and trends of the top, basal, and lateral seals.

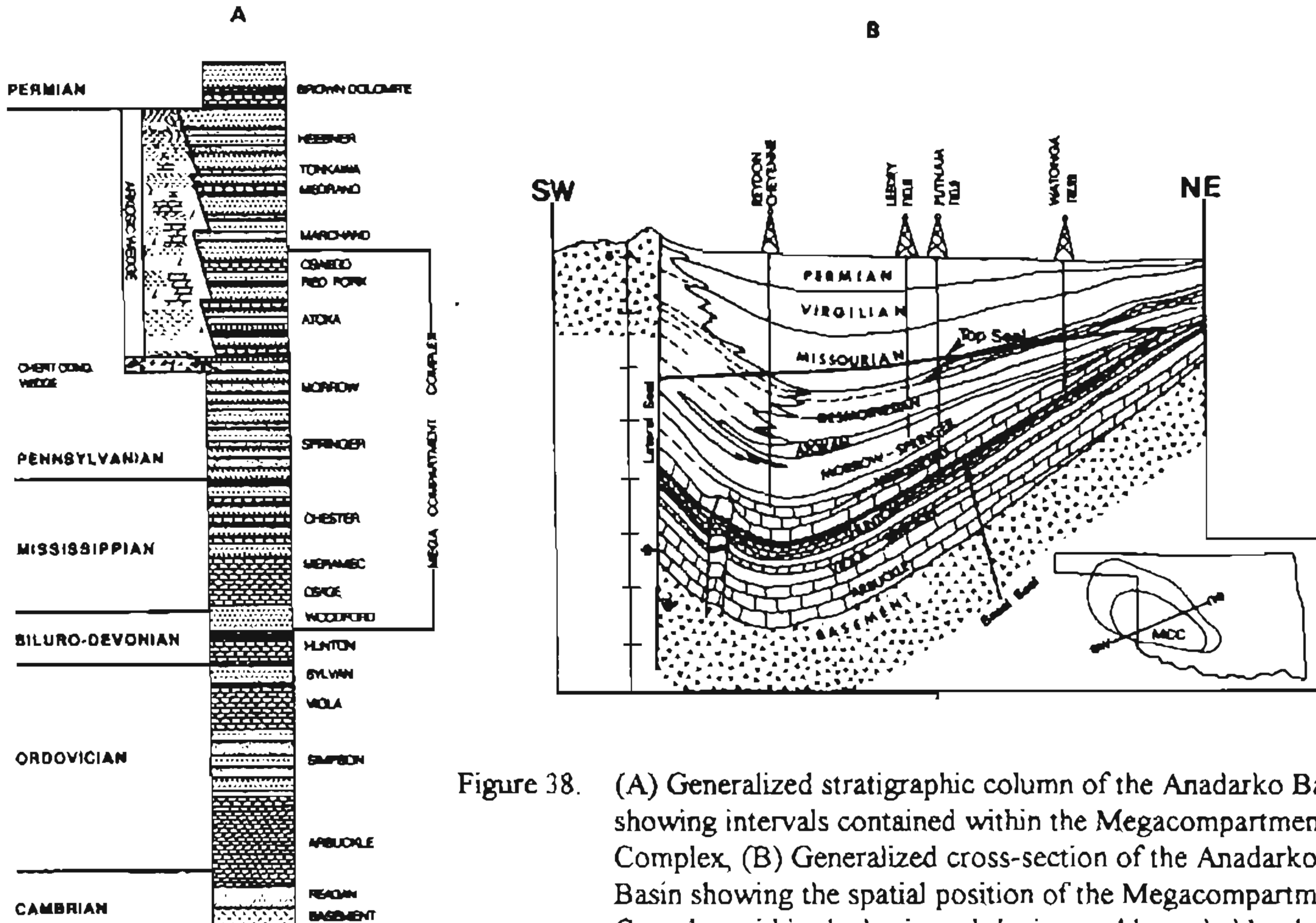


Figure 38. (A) Generalized stratigraphic column of the Anadarko Basin showing intervals contained within the Megacompartment Complex, (B) Generalized cross-section of the Anadarko Basin showing the spatial position of the Megacompartment Complex within the basin and the interval bounded by the top, basal, and lateral seals (from Al-Shaieb, 1991).

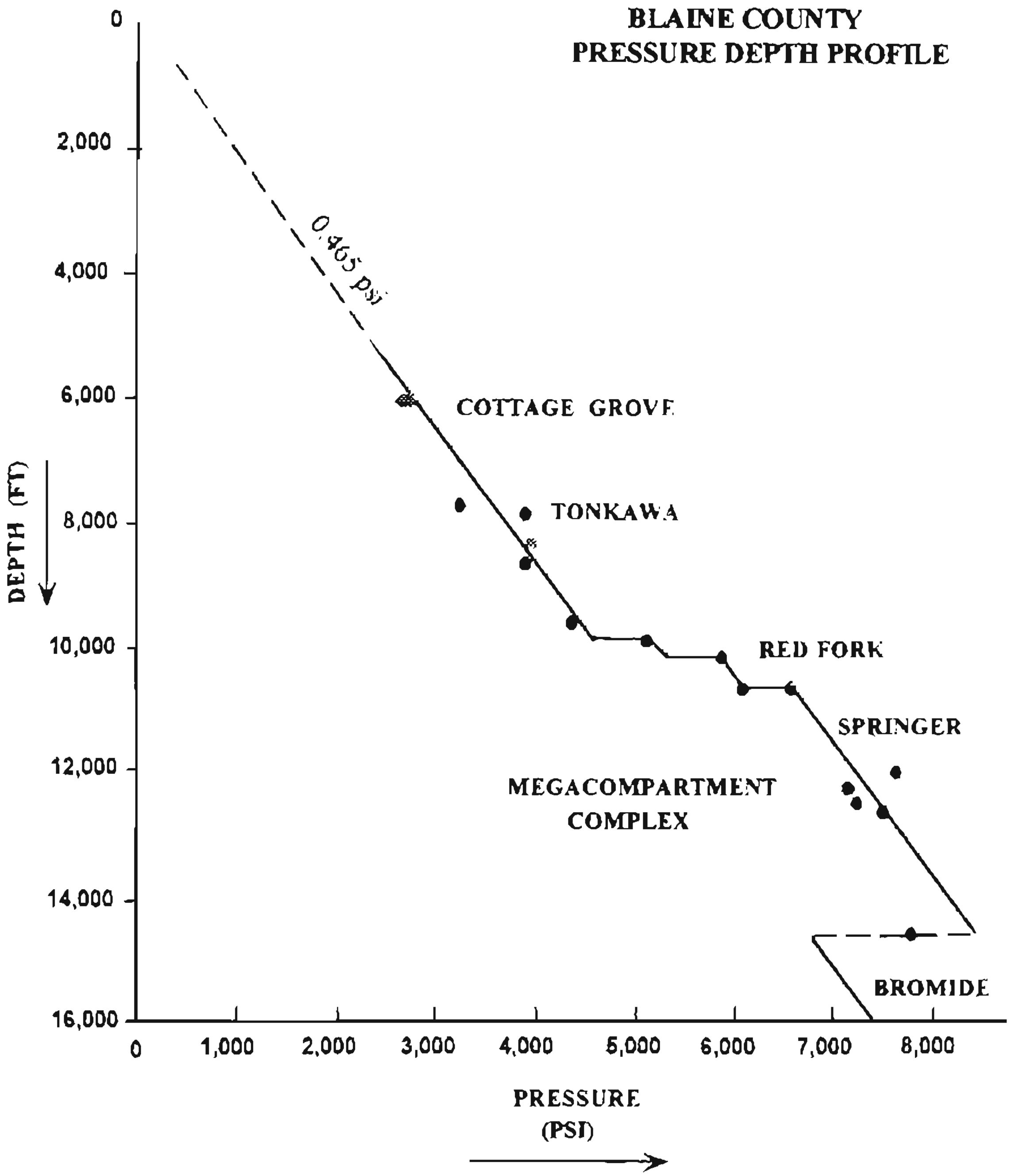


Figure 39. Pressure-depth profile from Blaine County, Oklahoma. Deviation of the curve to the right (higher pressure) identifies the megacompartment complex in the Red Fork and Springer intervals. Profile constructed using well pressure data.

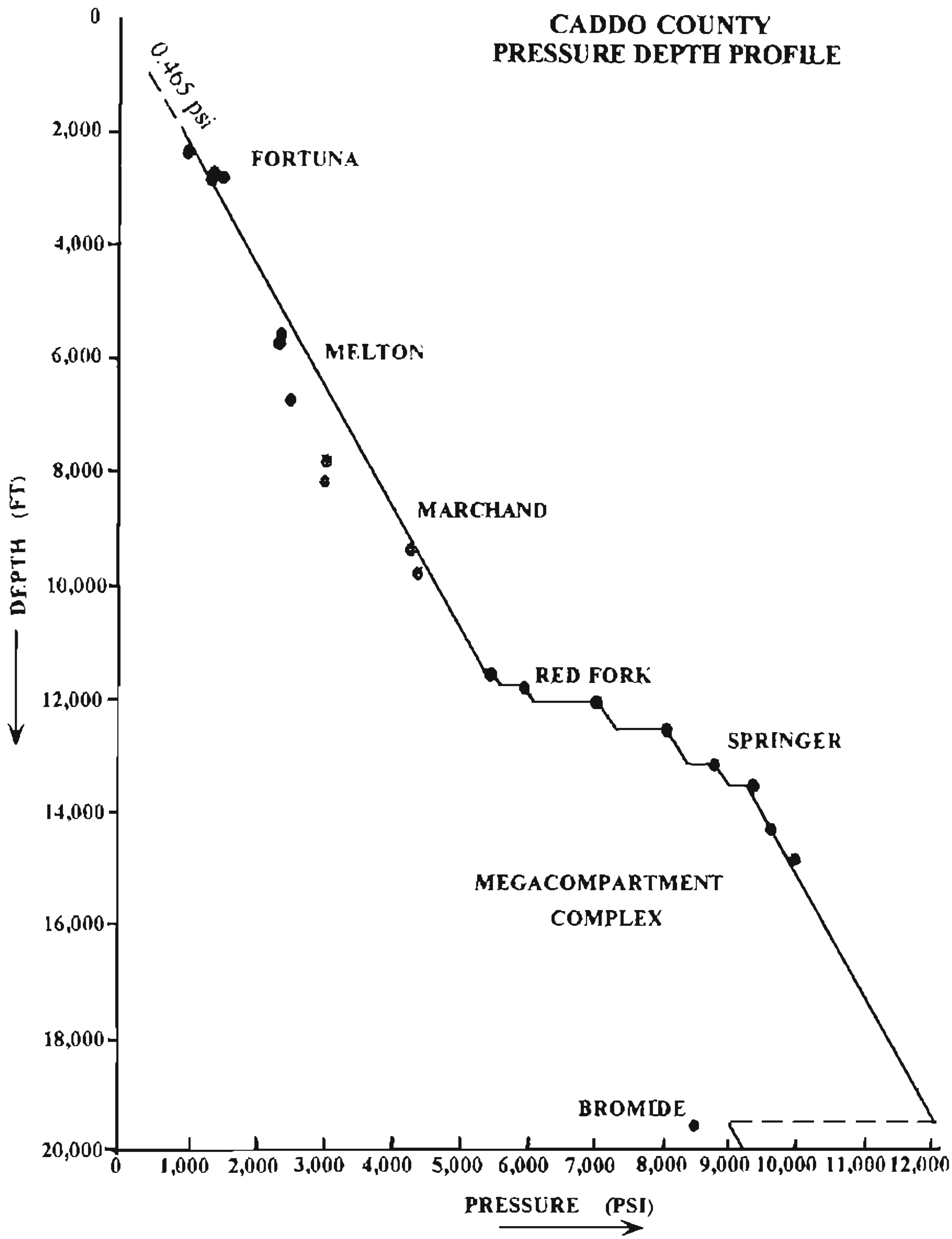


Figure 40. Pressure-depth profile from Caddo County, Oklahoma Deviation of the curve to the right (higher pressure) identifies the megacompartment complex in the Red Fork, Springer and Viola intervals. Profile constructed using well pressure data

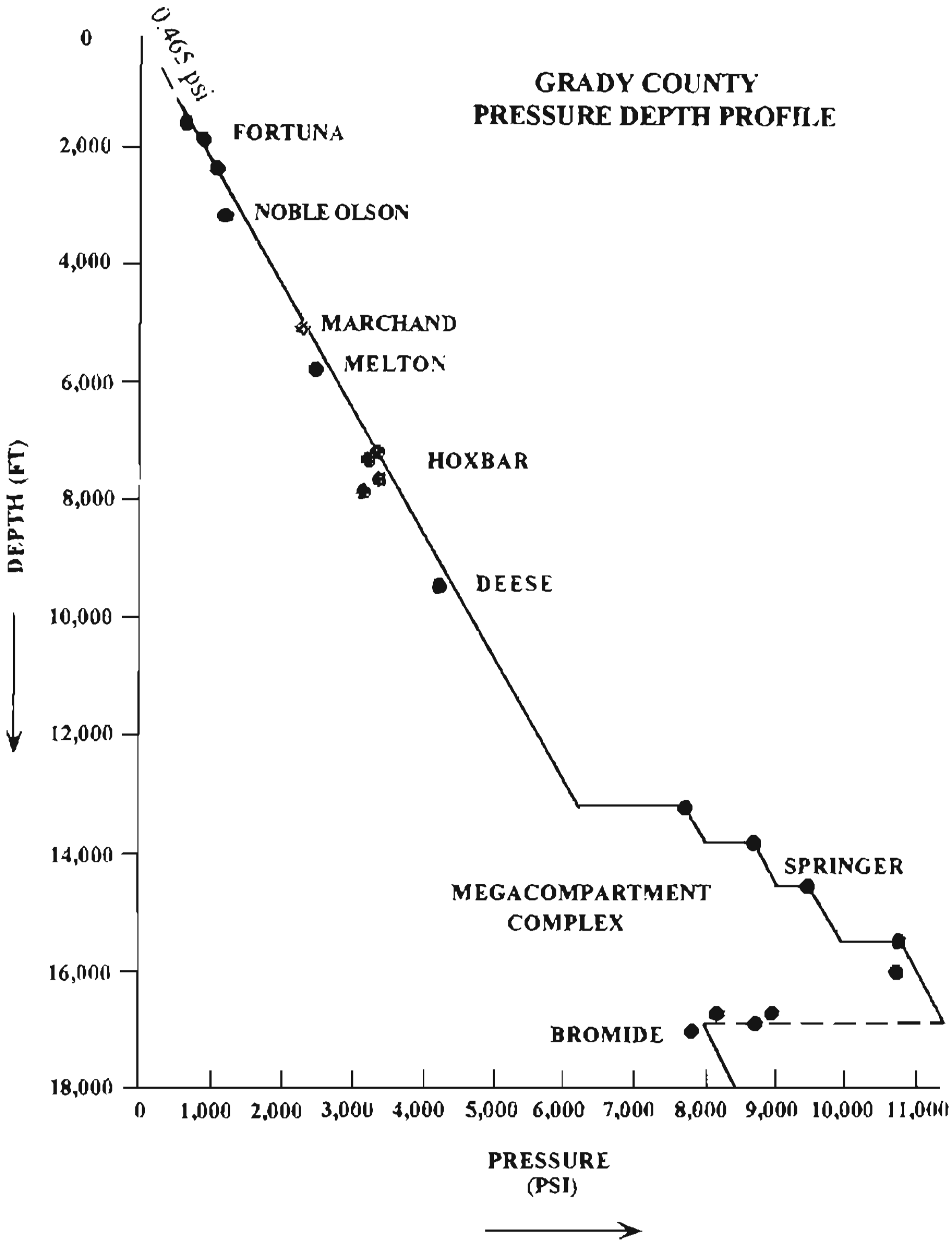


Figure 41. Pressure-depth profile from Grady County, Oklahoma Deviation of the curve to the right (higher pressures) identifies the megacompartment complex in the Springer interval Profile constructed using well pressure data

Level 2

Level 2 compartments consist of multiple, district or field-sized areas within a particular stratigraphic interval (Fig. 36). These compartments are approximately 20 to 30 miles long, 12 to 20 miles wide and approximately 400 to 600 feet thick (Al-Shaieb and others, 1993, p. 69).

Level 3

Level 3 compartments are single, small, field- or reservoir-sized subdivisions nested within Level 2 compartments (Fig. 36). These compartments are formed within reservoirs that compose a stratigraphic interval. Level 3 compartments are generally 2 to 4 miles long, less than 1 mile up to 3 miles wide and 10 to 100 feet thick (Al-Shaieb and others, 1993, p. 69).

CHAPTER V

DETRITAL AND DIAGENETIC CONSTITUENTS

Sandstones along a vertical transect through the megacompartment complex within the Anadarko Basin were analyzed for detrital and diagenetic constituents. These include the Fortuna sandstone (significantly above the top seal of the megacompartment complex), the Tonkawa, Marchand, Culp, and Melton sandstones (immediately above the top seal), the Red Fork and Springer sandstones (within the megacompartment complex), and the Bromide sandstone (below the basal seal).

Fortuna Sandstone

A summary listing of the detrital and diagenetic constituents and amounts of each are in Appendix B, p. 176.

Detrital Constituents

The detrital framework of the Fortuna sandstone studied consists of approximately 38 percent monocrystalline quartz and a trace amount of polycrystalline quartz. Some quartz grains contain vacuoles, needles or inclusions. Boehm lamellae were observed in several quartz grains and may represent intensive strain on the grain. Total feldspar content in the overall detrital composition is in trace amounts. Other detrital grains in trace to minor amounts include muscovite, biotite, zircon, tourmaline, hematite, and chlorite. Some muscovite, biotite and chlorite grains were deformed ductilely during compaction and are pseudomatrix. The detrital matrix is composed primarily of chlorite/illite and makes up 27.8 percent of the detrital composition. The Fortuna Sandstone is quartz wacke (Fig. 42).

Diagenetic Constituents

Cements The silica cement is composed of syntaxial quartz overgrowths and makes up 4.8 percent of the composition. Quartz overgrowths are distinguished from detrital quartz by chloritic/illitic "dust rims" which formed a thin coating on detrital grains. Quartz grains are in contact stages 0 to 2 (Fig. 43), indicating (1) grains are not in contact, or (2) grains that are in contact are touching at one point or along a grain face, and (3) slight compaction occurred.

Clays Authigenic clays in trace to minor amounts are chlorite, kaolinite, and illite. Chlorite is light green under plane-polarized light and is radiating fibrous pore-lining and pore-filling clay. Illite is an alteration product on detrital-grain surfaces such as feldspars. Kaolinite is pore-filling clay in stacked-booklet morphology, as seen under high magnification. X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p. 202.

Porosity Primary porosity composes 39.2 percent of the Fortuna sample. Primary porosity is intergranular porosity which was not obliterated by compaction. Secondary porosity is in 2 percent of the sample as moldic or intergranular porosity. Moldic porosity resulted from dissolution of detrital grains, and intergranular porosity resulted from dissolution of siliceous or clayey matrix.

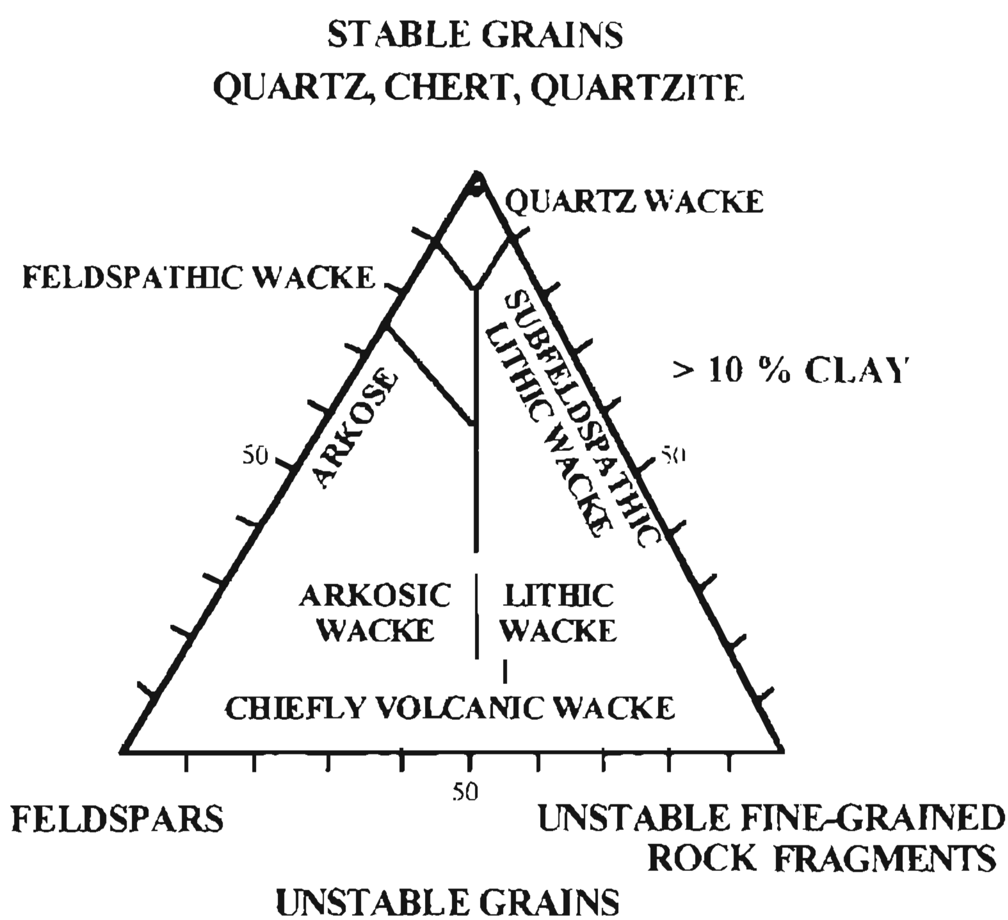


Figure 42. QRF sandstone-classification diagram (Williams, Turner, and Gilbert, 1953) of the Fortuna sandstone The Fortuna sandstone is classified as a quartz wacke.

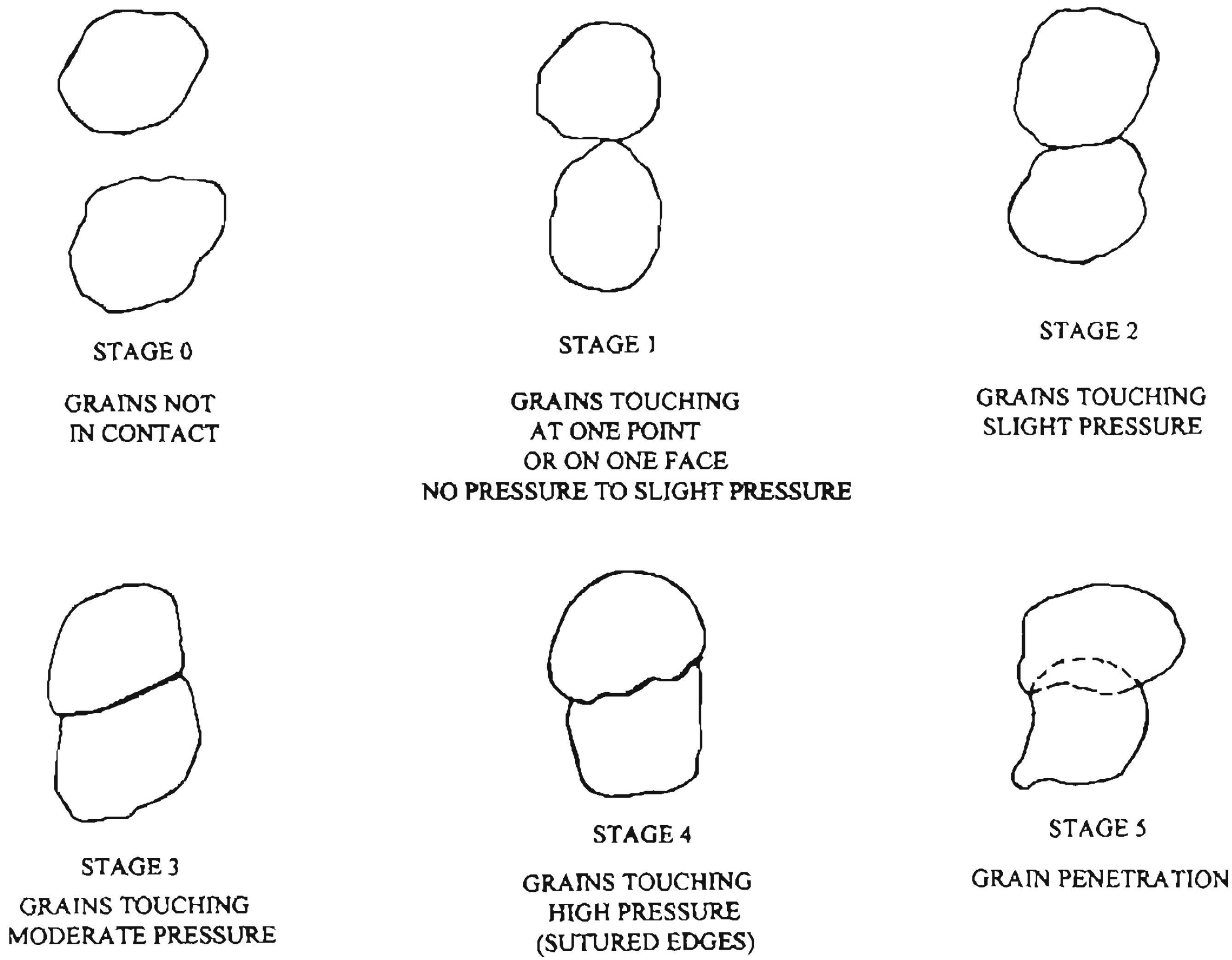


Figure 43. Diagram of Grain Contact Stages.

Tonkawa Sandstone

A summary listing of the detrital and diagenetic constituents and the amounts of each are in Appendix B, p. 177

Detrital Constituents

Monocrystalline quartz is the dominant framework grain, ranging from 54 6 to 72.4 percent. Some quartz grains contain vacuoles or inclusions Boehm lamellae were in several quartz grains and may represent intensive strain on the grain. A variety of feldspars is present in trace amounts Potassium feldspar commonly is in the untwinned form. Plagioclase feldspar is in the albite-twinned form Feldspar grains are in various stages of alteration, dissolution, and replacement, mostly from calcite cement Shale fragments are the dominant rock fragments, ranging from 0.4 to 18 percent. Chert and granophyres are in trace to minor amounts. Other detrital grains in trace to minor amounts include glauconite, fossil fragments, zircon, tourmaline, chlorite, and hematite. Glauconite grains are bright green and subangular to subrounded. The fossils are bryozoan and echinoderm fragments that have been replaced by calcite. Some chlorite grains were deformed ductilely during compaction and are pseudomatrix. The detrital matrix is composed primarily of chlorite/illite and makes up 7 to 10 percent of the detrital composition. The Tonkawa Sandstone is quartz arenite (Fig. 44) to subfeldspathic lithic arenite (Fig. 45)

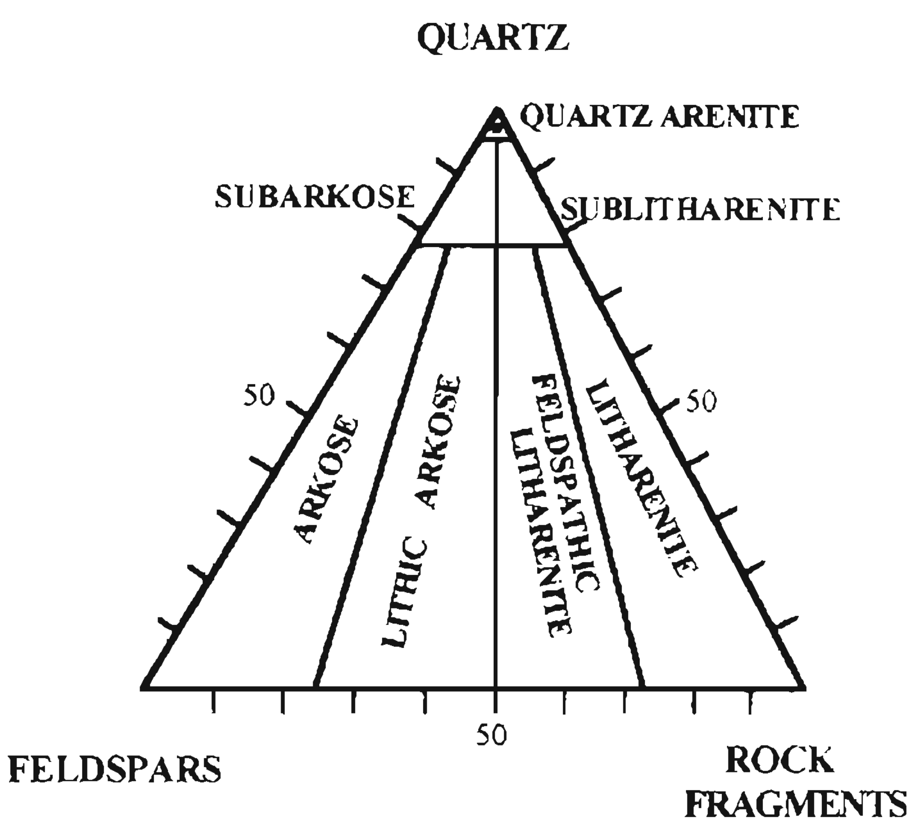


Figure 44 QRF sandstone-classification diagram (Folk, 1968) of the Tonkawa sandstone. The Tonkawa sandstone is classified as a quartz arenite.

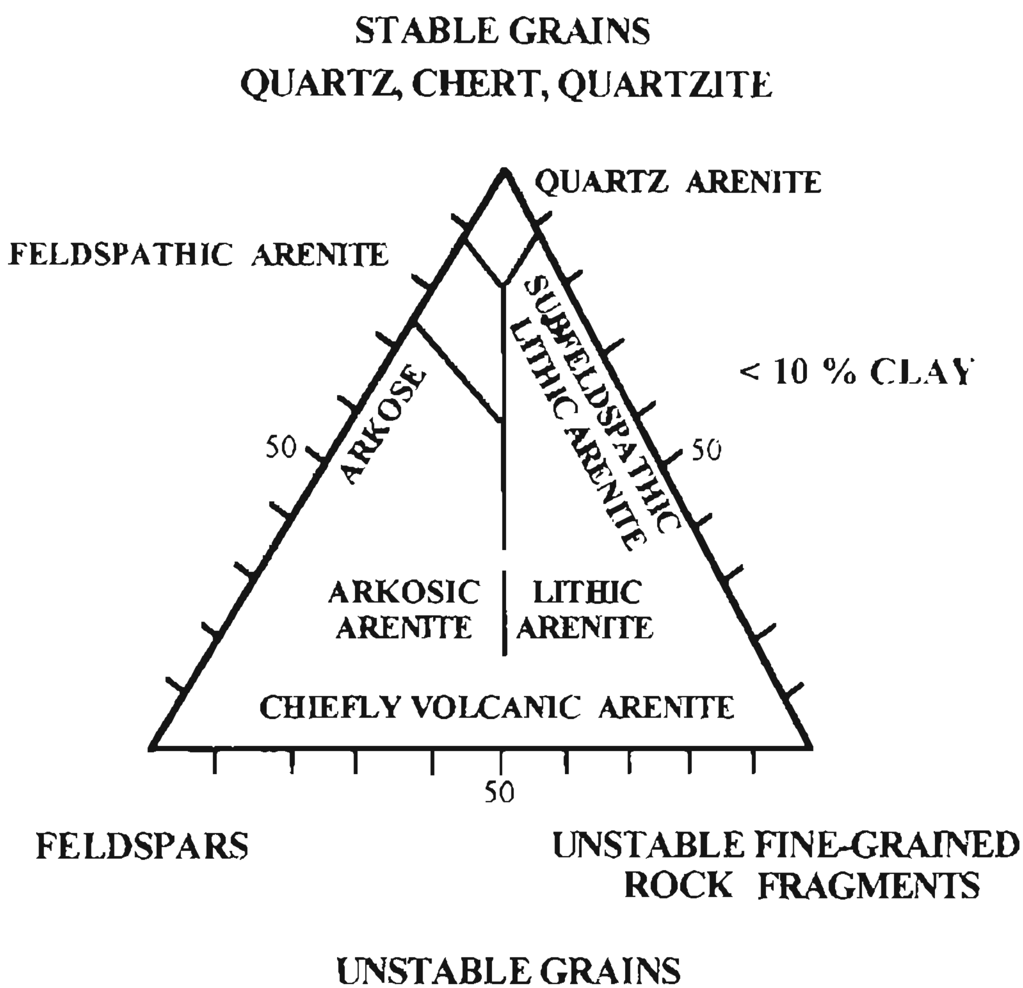


Figure 45 QRF sandstone-classification diagram (Williams, Turner, and Gilbert, 1953) of the Tonkawa sandstone The Tonkawa sandstone is classified as subfeldspathic lithic arenite.

Diagenetic Constituents

Cements Authigenic silica formed syntaxial quartz overgrowths and ranges from 10.75 to 17.5 percent. The quartz grains have chloritic/illitic "dust rims" that formed a thin coat on original grains and separated grains from the overgrowth. Quartz overgrowths formed euhedral crystal faces with sufficient pore space. Quartz grains are in contact stages 2 to 5 (Fig. 43). Grains were slightly to highly compacted and grain boundary penetration occurred.

Calcite cement ranges from 5 to 35.2 percent and dolomite is in trace amounts. The calcite cement has etched and replaced detrital grains such as quartz and fossil fragments. It occurred as poikilotopic and blocky cements. The dolomite cement is idiotopic.

Clays Kaolinite and chlorite are authigenic clays in minor amounts. Chlorite formed as a fibrous pore-lining clay and is light green under plane-polarized light. Kaolinite occurred as a pore-filling clay and is in stacked-booklet form, seen under high magnification. X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p. 203-205.

Organic material Organic residues are brown to black and in trace amounts. This material filled a stylolite and intergranular pore spaces.

Porosity Secondary porosity occurred in trace to minor amounts, as fractures, intergranular porosity, and moldic porosity. The intergranular porosity formed from the dissolution of cement, and the moldic porosity resulted from dissolution of detrital feldspars and rock fragments.

Marchand Sandstone

A summary listing of the detrital and diagenetic constituents and the amounts of each are in Appendix B, p. 178.

Detrital Constituents

The detrital framework of the Marchand sandstone studied consists of approximately 68.4 to 74.8 percent monocrystalline quartz and 1 to 2.6 percent polycrystalline quartz. Some grains contain vacuoles or inclusions. Etched grain boundaries and overgrowths resulted where quartz was in contact with carbonate cement Feldspars are in trace to minor amounts. Plagioclase feldspar is in the albite- and pericline-twinned forms and potassium feldspars are in the untwinned form Some feldspar grains were etched, dissolved, and replaced by calcite. Shale fragments. chert. and metamorphic rock fragments are in trace to minor amounts. Other detrital grains in trace to minor amounts include glauconite, fossil fragments, muscovite, zircon. tourmaline, hematite, and chlorite. Glauconite is light green subangular to subrounded grains. The fossil fragments were replaced by calcite cement. Some metamorphic rock fragments, muscovite, and chlorite grains were deformed ductilely during compaction and are pseudomatrix. The detrital matrix is composed of chlorite/illite and makes up 10 percent of the detrital material. The Marchand Sandstone is sublitharenite to quartz arenite (Fig. 46 and 47).

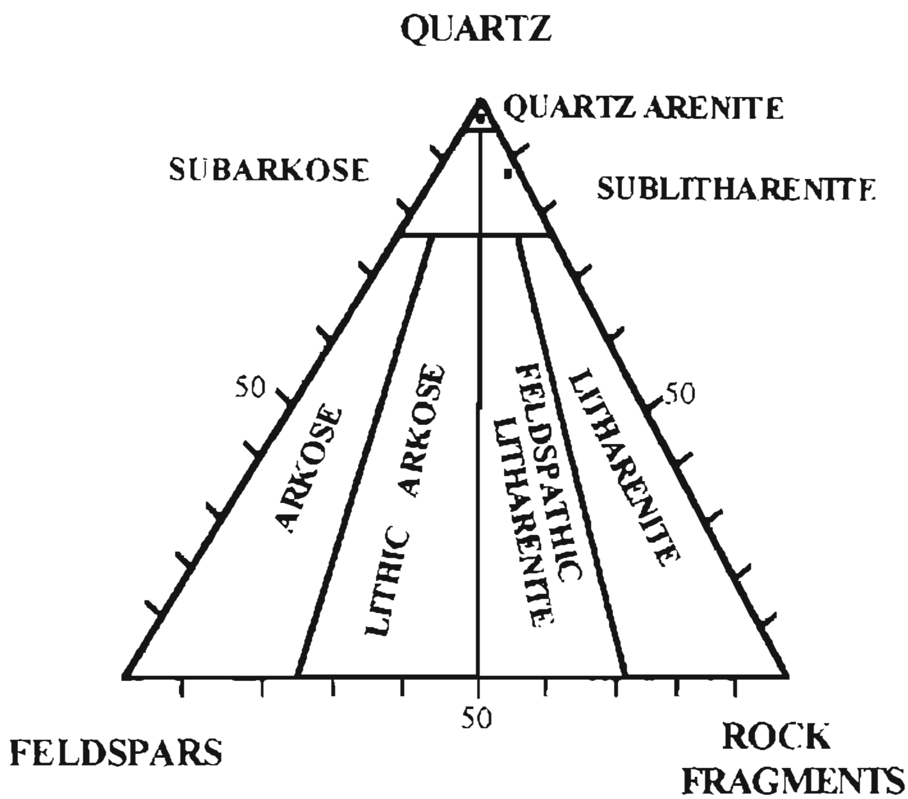


Figure 46. QRF sandstone-classification diagram (Folk, 1968) of the Marchand sandstone The Marchand sandstone is classified as a sublitharenite to quartz arenite

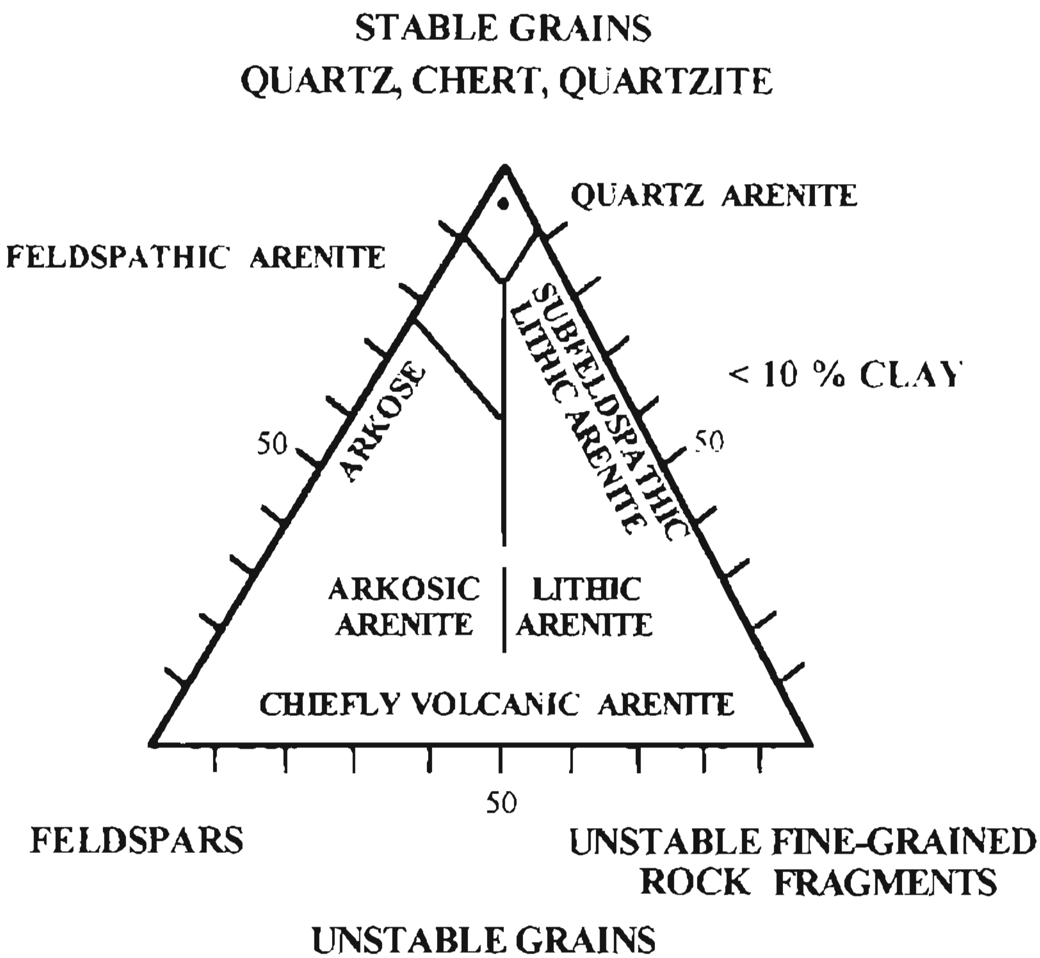


Figure 47. QRF sandstone-classification diagram (Williams, Turner, and Gilbert, 1953) of the Marchand sandstone The Marchand sandstone is classified as quartz arenite

Diagenetic Constituents

Cements Silica cement is syntaxial quartz overgrowths and makes up 9.75 to 13 25 percent of the composition. The quartz overgrowths are separated from detrital quartz by chloritic/illitic "dust rims" which formed a thin coat on detrital grains The overgrowths formed euhedral crystal faces with sufficient pore space. Quartz grains are in contact stages 3 to 5 (Fig 43) Grains were moderately to highly compacted, and grain boundary penetration occurred.

Calcite cement ranges from 4.2 to 19.2 percent. The calcite cement is in blocky form and has etched, dissolved, and replaced detrital grains such as quartz and feldspar Hematite cement is bright reddish orange in plane-polarized light

Clays Chlorite formed in minor amounts and is a light green pore-lining clay, as seen in plane-polarized light. Kaolinite occurred as a pore-filling clay and is in stacked-booklet form, seen under high magnification. Illite is an alteration product on surfaces of detrital feldspars. X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p. 206-208

Organic material Organic material is brown to black and is in trace to minor amounts. This material filled fracture areas and intergranular pore spaces

Porosity Primary porosity composes up to 11.6 percent of the rock sample as intergranular porosity that was preserved by clay coatings on detrital grains. These clay coatings inhibited precipitation of cementing materials Secondary porosity is in trace to minor amounts, as moldic porosity or intergranular porosity Moldic porosity resulted from dissolution of detrital grains; the intergranular porosity developed from dissolution of silica or other material.

Culp Sandstone

A summary listing of the detrital and diagenetic constituents and the amounts of each are in Appendix B, p. 179.

Detrital Constituents

Monocrystalline quartz is the dominant framework grain, ranging from 74.2 to 82.6 percent. Some quartz grains contain vacuoles, inclusions, or needles. Boehm lamellae were in several quartz grains and may represent intensive strain. Several feldspar types are present in trace to minor amounts. Potassium feldspar commonly is in the untwinned form. Plagioclase feldspar is in the albite- and pericline-twinned forms. Feldspar grains are in various stages of dissolution and replacement by calcite cement. Rock fragments in trace amounts include shale, metamorphic rock fragments and granophyres. Other detrital grains include muscovite, zircon, tourmaline, chlorite, hematite, and fossil fragments. Fossil fragments are echinoderms and bryozoans that have been replaced by calcite. Some of the metamorphic rock fragments, muscovite, and chlorite grains were deformed ductilely during compaction and are pseudomatrix. The Culp Sandstone is quartz arenite (Fig. 48).

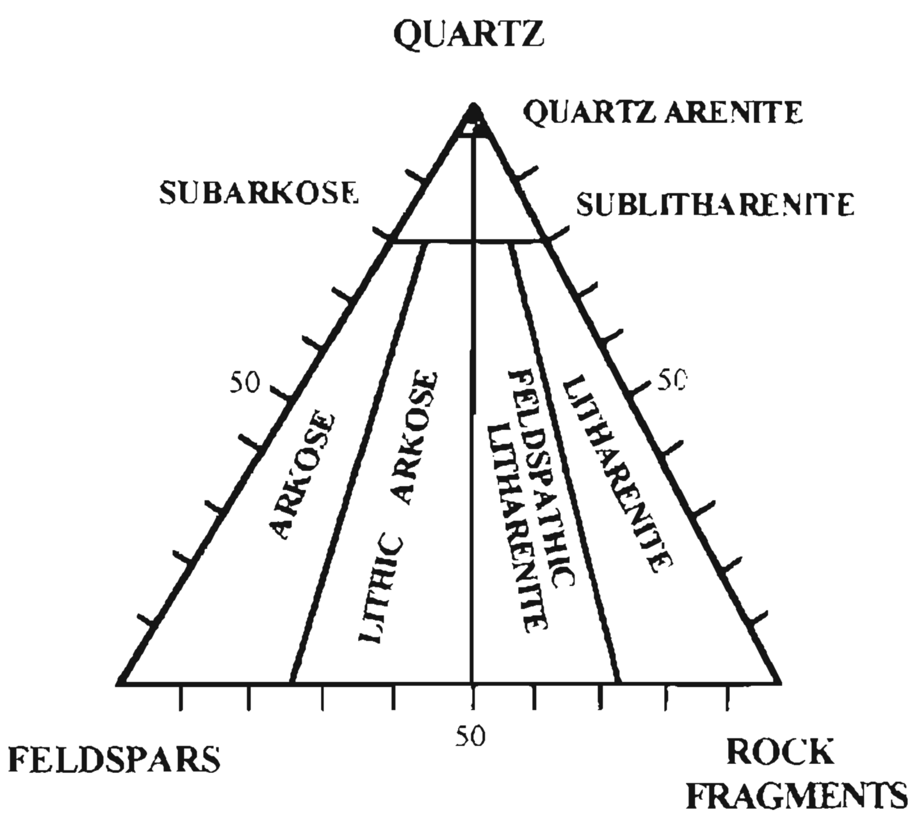


Figure 48. QRF sandstone-classification diagram (Folk, 1968) of the Culp sandstone The Culp sandstone is classified as a quartz arenite.

Diagenetic Constituents

Cements Authigenic silica is in syntaxial quartz overgrowths and ranges from 9.75 to 12.25 percent. Quartz grains have chloritic/illitic "dust rims" that formed a thin coating on grains that separated the grain from the overgrowth. Quartz overgrowths formed euhedral crystal faces with sufficient pore space. Quartz grains are in contact stages 3 to 5 (Fig. 43) Grains were moderately to highly compacted, and boundary penetration occurred.

Calcite cement ranges from 4.4 to 13 8 percent. The calcite cement etched and replaced adjacent quartz and feldspar grains It occurs as poikilotopic and blocky cements

Clays Chlorite, kaolinite, and illite are authigenic clays in trace to minor amounts Chlorite is a fibrous pore-filling clay and light green in plane-polarized light Kaolinite is a pore-filling clay with stacked-booklet morphology Illite is an alteration product on surfaces if detrital feldspars. X-ray diffraction data. which aided in identifying clays, is shown in Appendix D, p 209-210

Porosity Secondary porosity ranges from 3 8 to 4 0 percent and is intergranular or moldic porosity. Intergranular porosity is the result of dissolution of cement, and moldic porosity resulted from the dissolution of detrital grains

Melton Sandstone

A summary listing of the detrital and diagenetic constituents and the amounts of each are in Appendix B, p. 180.

Detrital Constituents

Monocrystalline quartz is the dominant framework grain at 72.4 percent. Some quartz grains contain vacuoles, inclusions or needles. Plagioclase feldspar is in albite- and pericline-twinned forms, in minor amounts. Feldspar grains are in various stages of alteration, dissolution, and replacement. Rock fragments include chert, metamorphic rock fragments and granophyres, in trace to minor amounts. Other detrital grains in trace to minor amounts include glauconite, fossil fragments, muscovite, tourmaline, collophane, and hematite. Glauconite is green, subangular to subrounded grains. The fossils are echinoderm fragments, replaced by calcite. Some metamorphic rock fragments and muscovite grains were deformed ductilely due to compaction and are pseudomatrix. The Melton Sandstone is quartz arenite (Fig. 49).

Diagenetic Constituents

Cements Authigenic silica is in syntaxial quartz overgrowths and makes up 7.25 percent of the composition. Quartz grains have chloritic/illitic "dust rims" that formed a thin coating separating the grain from the overgrowth. Quartz overgrowths formed euhedral crystal faces with sufficient pore space. Quartz grains are in contact stages 3 to 5 (Fig. 43). Grains were moderately to highly compacted, and grain boundary penetration

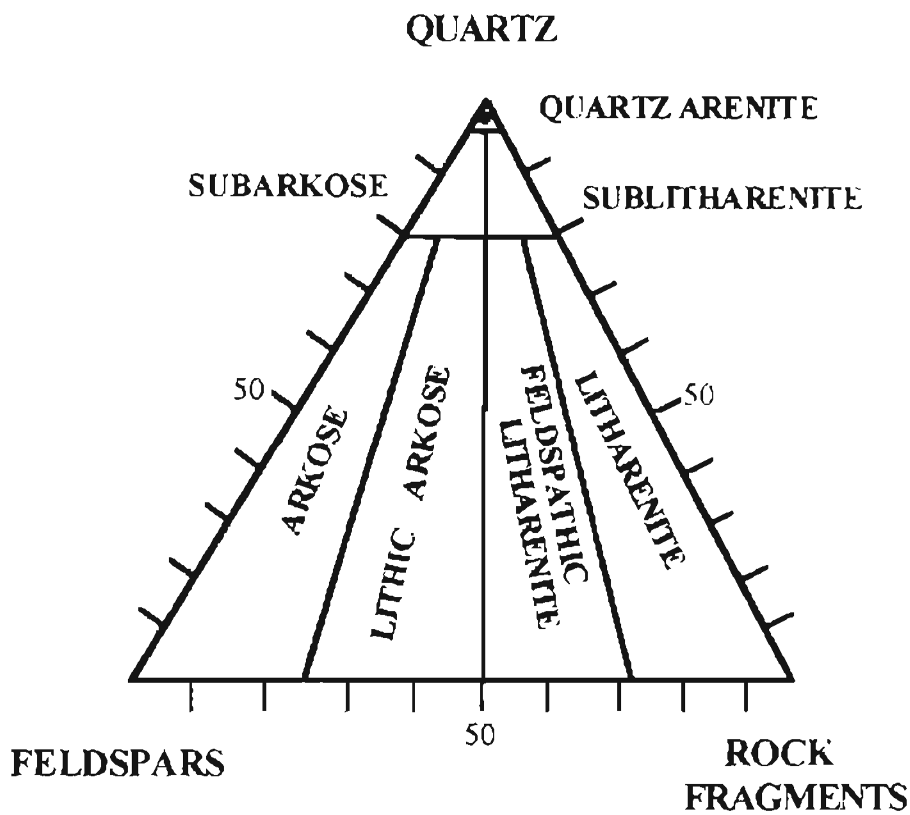


Figure 49. QRF sandstone-classification diagram (Folk, 1968) of the Melton sandstone. The Melton sandstone is classified as a quartz arenite.

occurred

Calcite cement composes 5.8 percent of the rock sample. Calcite has etched the adjacent quartz grains. Calcite cement has replaced quartz, feldspar, and fossil fragments. It is poikilotopic and blocky cements.

Clays Chlorite, kaolinite and illite are authigenic clays in minor amounts. Chlorite is a fibrous pore-lining clay and light green under plane-polarized light. Kaolinite is a pore-filling clay and forms stacked booklets, seen under high magnification. Illite is an alteration product on feldspar grain surfaces. X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p. 211

Porosity Secondary porosity is 3.4 percent of the sample, as intergranular porosity formed from dissolution of cement

Red Fork Sandstone

A summary listing of the detrital and diagenetic constituents and the amount present is in Appendix B, p. 181-182.

Detrital Constituents

The detrital framework of the Red Fork sandstone studied consists of approximately 15.4 to 54 0 percent monocrystalline quartz and trace to minor amounts of polycrystalline quartz. Some quartz grains contain vacuoles or inclusions The total detrital plagioclase feldspar content is trace amounts to 4.2 percent. The dominant feldspar is plagioclase, which showed albite-twinning. Potassium feldspars are in trace amounts in the untwinned form and in the carlsbad-twinned form. Microcline is in trace amounts and is identified by grid-twinning. Rock fragments include shale, chert, carbonate-rock fragments, and metamorphic-rock fragments, in trace amounts to 30.4 percent, depending on the sample under inspection. Other detrital grains in trace to minor amounts include glauconite, muscovite, biotite, zircon, tourmaline, hematite, and chlorite. The green, subangular to subrounded glauconite grains are in trace amounts. Some metamorphic rock fragments, muscovite, biotite and chlorite grains were deformed ductilely during compaction and are pseudomatrix. The detrital matrix is composed of chlorite and illite, ranging from 3 to 18.4 percent. The detrital matrix is difficult to separate from the authigenic clays. The Red Fork Sandstone is lithic wacke, subfeldspathic lithic wacke, and subfeldspathic lithic arenite (Fig. 50 and 51).

Diagenetic Constituents

Cements Silica cement is syntaxial quartz overgrowths, ranging from 1.75 to 7.75 percent. Quartz overgrowths are distinguished from detrital quartz by chloritic/illitic "dust rims" which formed a thin coating on the detrital grain. The overgrowths formed euhedral crystal faces with sufficient pore space. Quartz grains are in contact stages 0 to 3 (Fig. 43). Some quartz grains are not in contact and for grains in contact, slight to moderate compaction occurred.

Calcite cement has etched and replaced some quartz and feldspar grains.

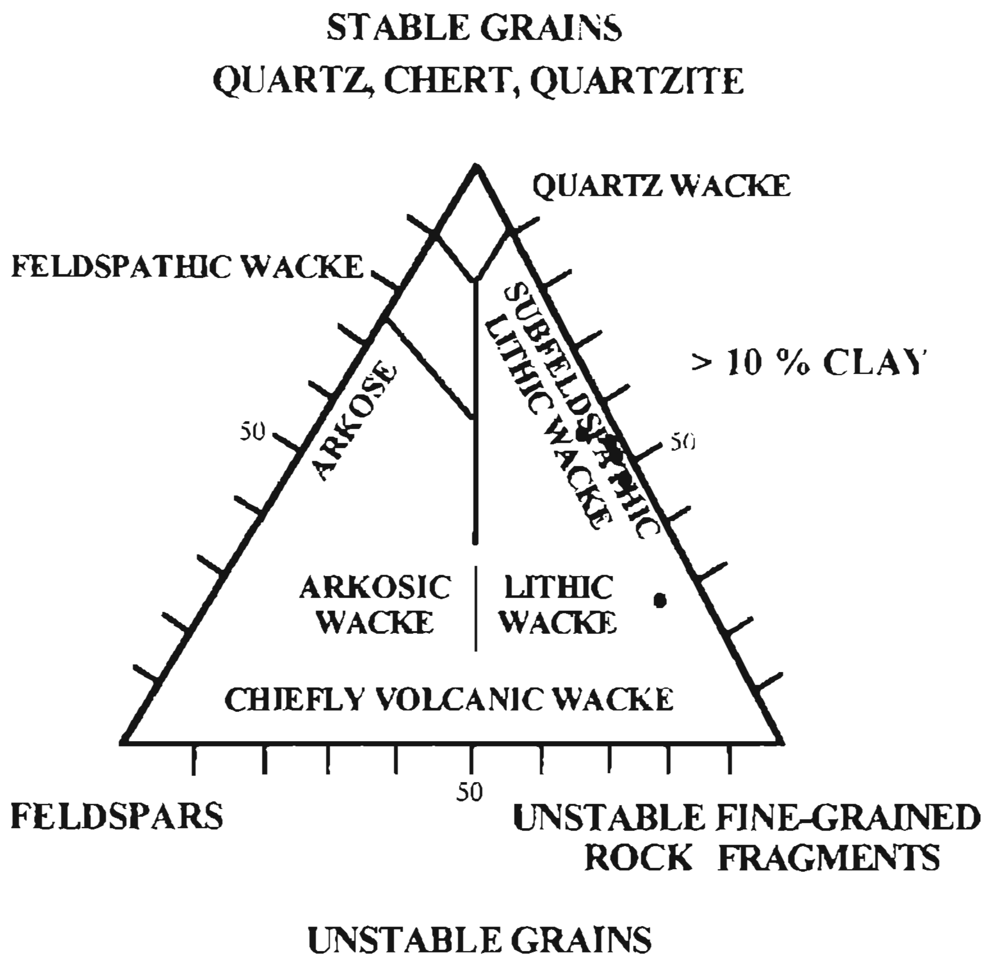


Figure 50. QRF sandstone-classification diagram (Williams, Turner, and Gilbert, 1953) of the Red Fork sandstone. The Red Fork sandstone is classified as subfeldspathic lithic wacke to lithic wacke

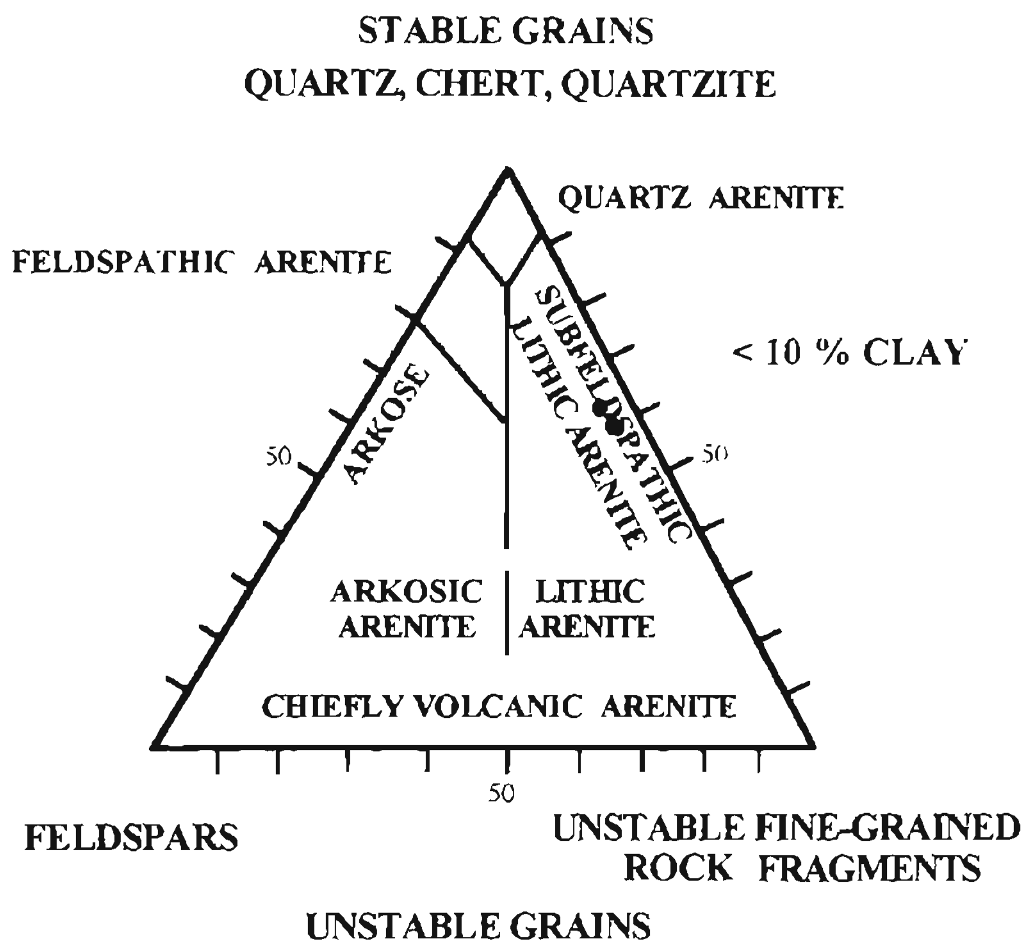


Figure 51. QRF sandstone-classification diagram (Williams, Turner, and Gilbert, 1953) of the Red Fork sandstone. The Red Fork sandstone is classified as subfeldspathic lithic arenite

Clays Authigenic clays in trace to minor amounts are chlorite, kaolinite, and illite. Chlorite is light green under plane-polarized light and is a radiating fibrous pore-lining clay. Illite is grain coatings and an alteration product on detrital feldspar surfaces. The authigenic clays are difficult to separate from the detrital clay matrix. X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p. 212-218

Organic material Organic residues are amorphous, brown to black and compose 0 4 to 8 percent of the sample This material filled fractures and intergranular pore spaces

Porosity Secondary porosity is in trace amounts up to 1 percent as fracture porosity or intergranular porosity. Intergranular porosity resulted from dissolution of silica or clay matrix.

Springer Sandstone

A summary listing of the detrital and diagenetic constituents and the amounts of each are in Appendix B, p 183.

Detrital Constituents

Monocrystalline quartz is the dominant framework grain, ranging from 56.2 to 72.6 percent. Polycrystalline quartz, as composite grains, is in trace to minor amounts. Some quartz grains contain vacuoles, inclusions, or needles. Boehm lamellae were in several quartz grains and may represent intensive strain. Plagioclase feldspar is in trace amounts in albite- and pericline-twinned forms Other detrital grains in trace to minor amounts include fossil fragments, zircon, tourmaline, collophane, and hematite. The Springer Sandstone is quartz arenite (Fig. 52).

Diagenetic Constituents

Cements Authigenic silica is in syntaxial quartz overgrowths and ranges from 9.2 to 11.75 percent. Quartz grains have chloritic/illitic "dust rims" that separated the grain from the overgrowth Quartz overgrowths formed euhedral crystal faces with sufficient pore space. Quartz grains are in contact stages 3 to 5 (Fig. 34). Grains were moderately to highly compacted, and grain boundary penetration occurred.

Calcite cement ranges from trace amounts to 39.2 percent. Calcite cement etched and replaced adjacent quartz and feldspar and replaced some fossil fragments. The calcite cement is poikilotopic and blocky

Clays Chlorite and kaolinite are authigenic clays in trace to minor amounts Chlorite is a fibrous pore-filling and pore-lining clay and is light green in plane-polarized light. Kaolinite is a pore-filling clay in stacked-booklet morphology, seen under high magnification X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p. 219-221.

Organic material Organic residues are brown to black and filled fracture areas

Porosity Primary porosity composes 4.0 to 16.6 percent of the sample, as intergranular porosity preserved by clay coatings on detrital grains. These clay coatings

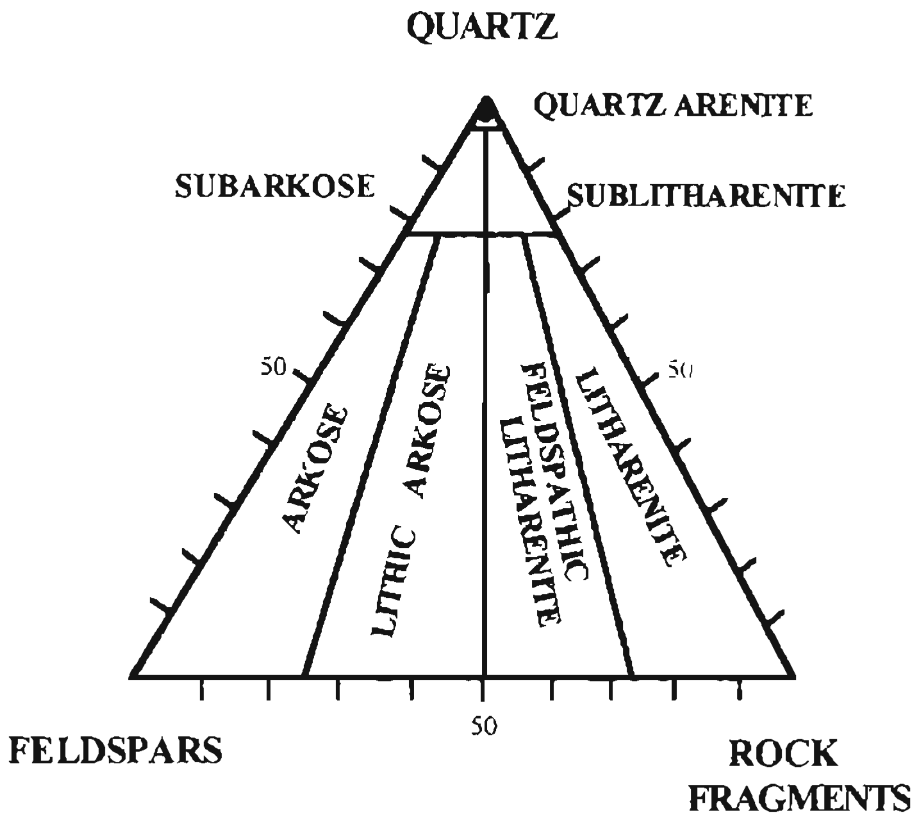


Figure 52. QRF sandstone-classification diagram (Folk, 1968) of the Springer sandstone. The Springer sandstone is classified as a quartz arenite.

inhibited precipitation of cement Secondary porosity ranges from 2.0 to 3.0 percent as fracture porosity, intergranular porosity, or moldic porosity Intergranular porosity formed from dissolution of cement and the moldic porosity resulted from dissolution of detrital grains.

Bromide Sandstone

A summary listing of the detrital and diagenetic constituents and the amounts of each are in Appendix B, p. 184.

Detrital Constituents

The detrital framework of the Bromide sandstone studied consists of 54 4 to 94.6 percent monocrystalline quartz. Some quartz grains contain vacuoles or inclusions Other detrital grains in trace amounts include zircon, collophane, and hematite. The Bromide Sandstone is quartz arenite (Fig. 53).

Diagenetic Constituents

Cements The silica cement is composed of syntaxial quartz overgrowths and ranges from 9.75 to 14.75 percent. Quartz overgrowths are distinguished from detrital quartz by chloritic/illitic "dust rims" which formed a thin coating on detrital grains. The overgrowths formed euhedral crystal faces with sufficient pore space Quartz grains are in contact stages 3 to 5 (Fig 43) Grains were moderately to highly compacted and grain boundary penetration occurred

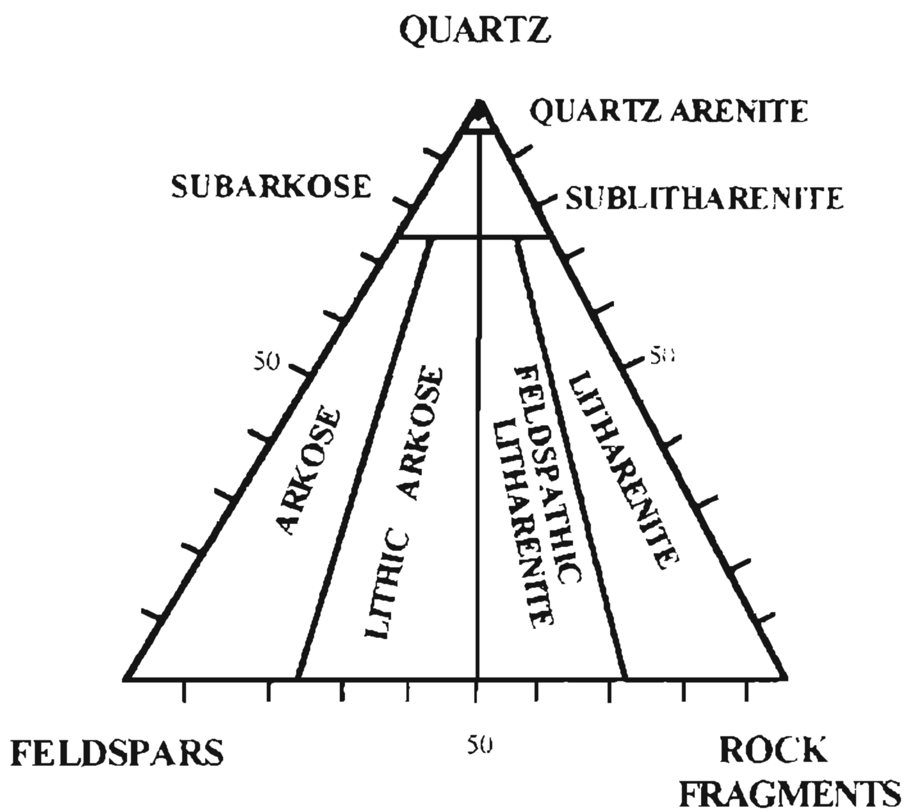


Figure 53. QRF sandstone-classification diagram (Folk, 1968) of the Bromide sandstone The Bromide sandstone is classified as a quartz arenite

Calcite cement is as much as 11.8 percent and dolomite is as much as 43.2 percent Calcite etched adjacent quartz grains and is blocky cement. The dolomite cement is idiotopic.

Clays Authigenic clays in trace to minor amounts are chlorite and illite. Chlorite is light green under plane-polarized light and is a radiating fibrous pore-lining clay. Illite is pore-lining clay X-ray diffraction data, which aided in identifying clays, is shown in Appendix D, p 222-224.

Organic material Organic residues are brown to black and filled a stylolite

Porosity Secondary porosity is in trace amounts to 7 percent as fracture or intergranular porosity. Intergranular porosity resulted from dissolution of silica.

CHAPTER VI

SEALING MECHANISMS

The purpose of this chapter is to compare the processes that preserved or occluded primary porosity in shallow to deeply buried sandstones within the Anadarko Basin. Information in this chapter is summarized in Appendix E p. 225

For the purposes of this study sandstones were grouped and divided as follows. shallow buried sandstones, approximately 2,000 feet deep are significantly above the top seal of the megacompartment complex; moderately buried sandstones, approximately 8,900 to 10,500 feet deep are immediately above the top seal; and deeply buried sandstones, approximately 10,900 to 14,150 feet deep are within the megacompartment complex or below the basal seal. Appendix F p. 234 is a table showing the location of the sandstones with respect to the megacompartment complex

Shallow Burial Depth

Fortuna Sandstone

The Fortuna sandstone is the shallowest interval studied with a depth of 2,025 to 2,162 feet. Slight compaction is evidenced by (1) quartz-grain contacts in stages 0 to 2, some grains were not in contact while grains that were in contact had been only slightly compacted (Fig. 54); (2) trace amounts of muscovite, biotite and chlorite have been deformed ductilely and are pseudomatrix (Fig. 55); and (3) forty percent of the

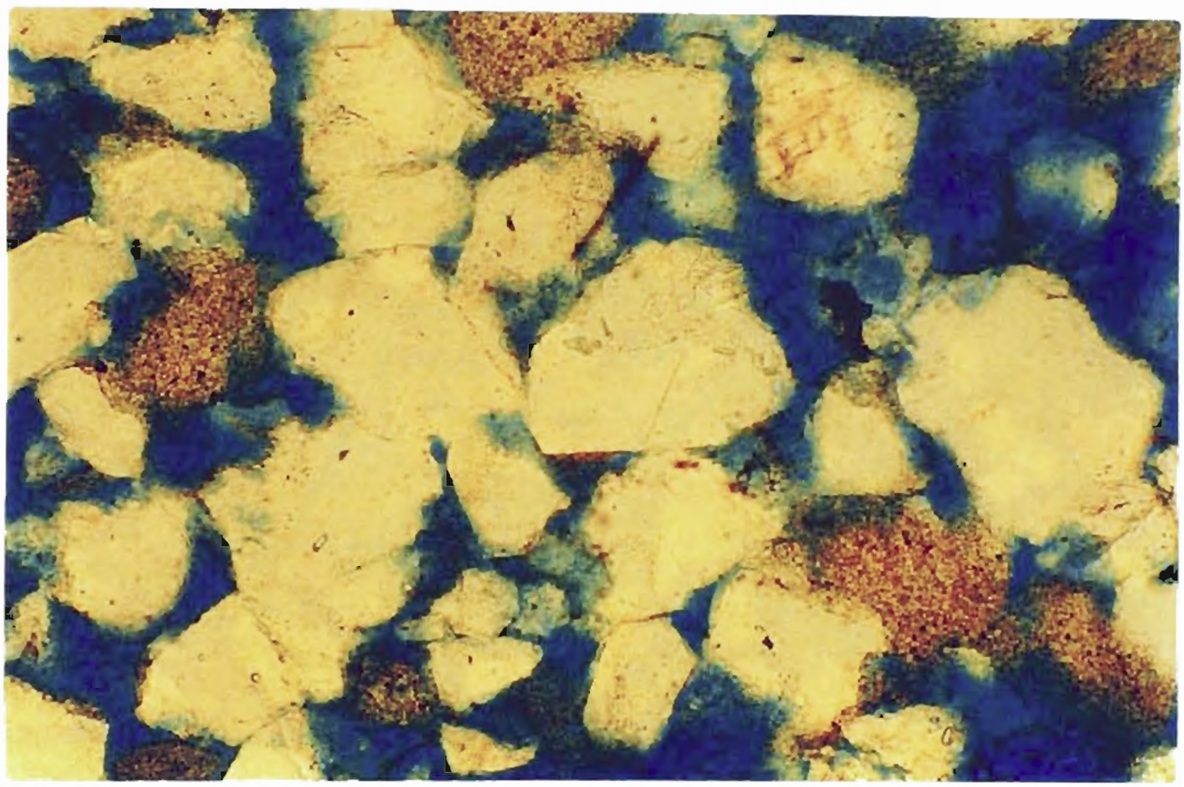


Figure 54. Grain contact stages 0 to 2 in the Fortuna sandstone. PPL. 20X.

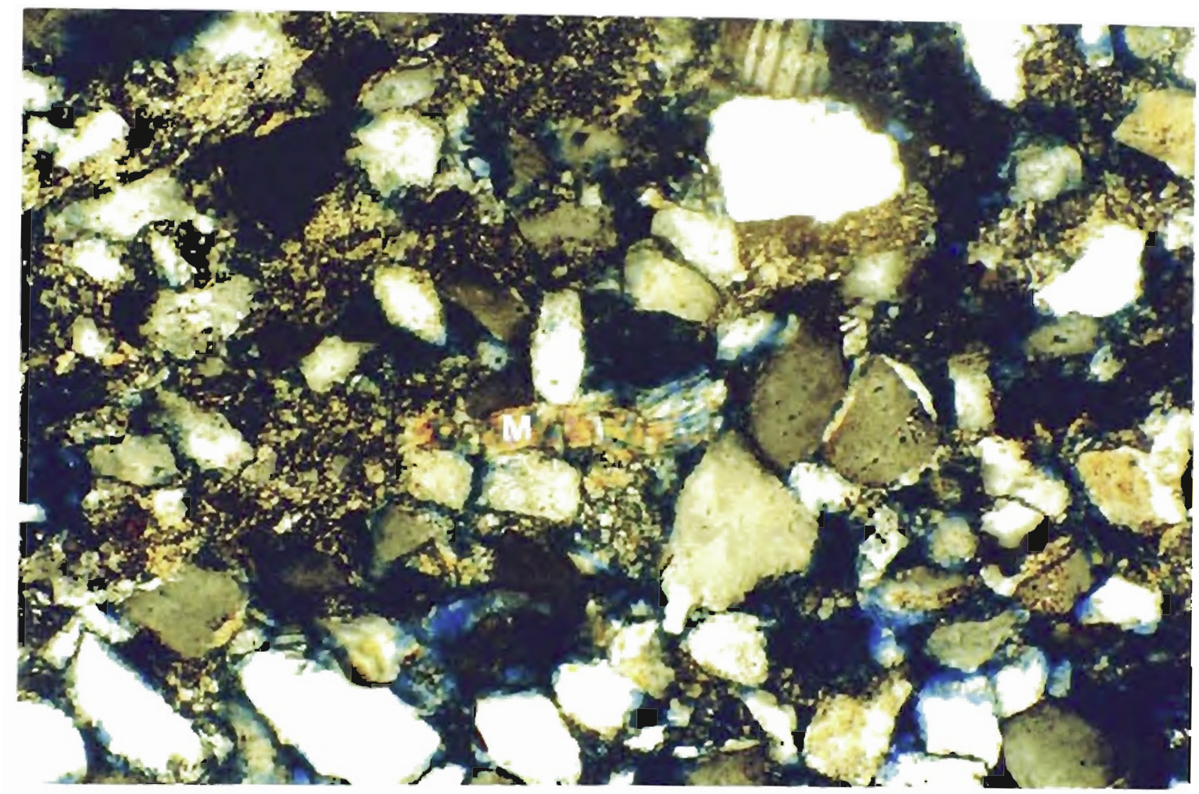


Figure 55. Muscovite grain (M) ductilely deformed in the Fortuna sandstone. XN. 20X.

primary porosity was not occluded by compaction (Fig. 56). Some primary porosity was occluded by pore-filling kaolinite (Fig. 57) and chlorite (Fig. 58) Clay matrix enclosed quartz grains and partially occluded primary porosity in some areas of the sample In these areas are minor amounts of secondary intergranular porosity. Silica is in minor amounts as quartz-overgrowth cement (Fig. 59). The source of silica could have been from an adjacent area where quartz grains underwent dissolution and/or dissolution of feldspars within the sandstone (Fig. 60) Due to the shallow burial depth, the grains were not compacted enough to be a substantial source of silica from pressure dissolution.

Moderate Burial Depth

Tonkawa Sandstone

Depth of the Tonkawa sandstone studied is 8,953 to 8,959 feet. The Tonkawa sandstone was subjected to compaction as evidenced by (1) grain contact stages 2 to 5, grains were slightly to highly compacted with some grain-boundary suturing and penetration (Fig. 61); (2) occlusion of primary porosity; (3) formation of pseudomatrix by ductilely deformed detrital grains; and (4) silica dissolution from quartz-grain pressure solution. In this sandstone primary porosity was occluded and secondary porosity is in trace amounts to 0.8 percent. Primary porosity was occluded by compaction, cementation, clay matrix, and pore-filling clay (Fig. 62). Silica precipitation is in moderate amounts as quartz overgrowth cement (Fig. 63) The silica could have

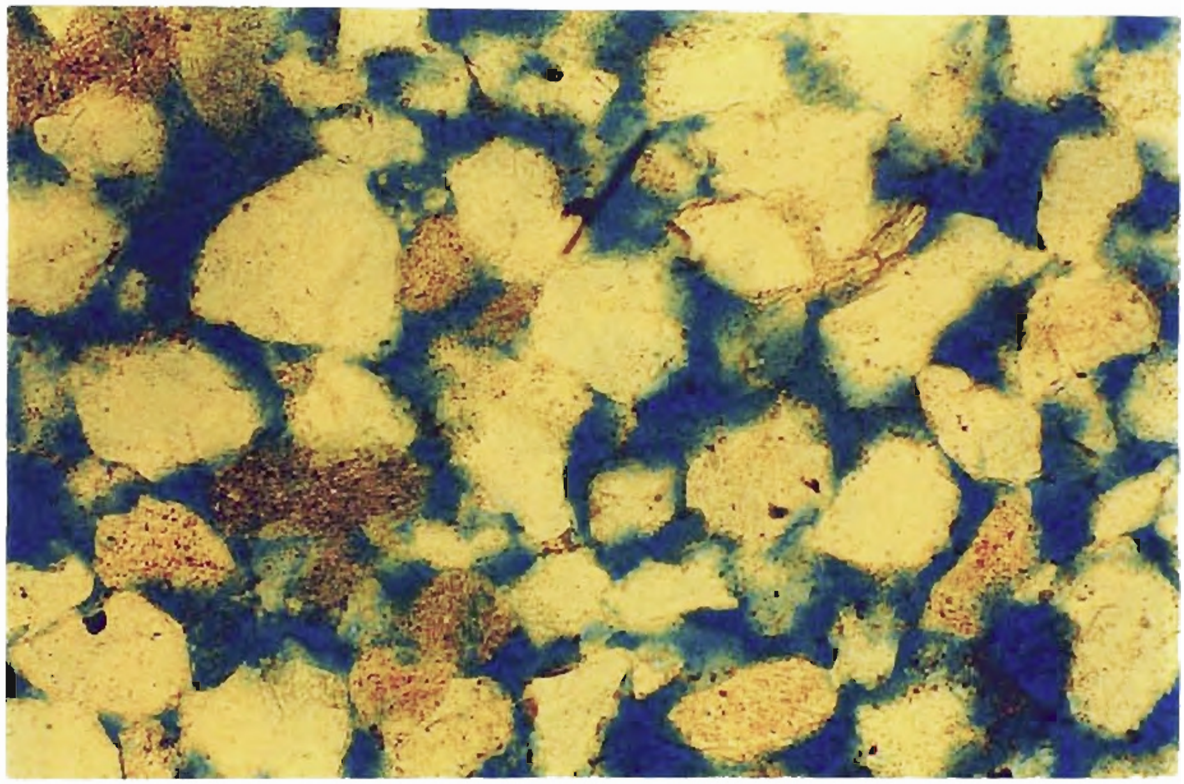


Figure 56. Primary porosity in the Fortuna sandstone. PPL. 20X.

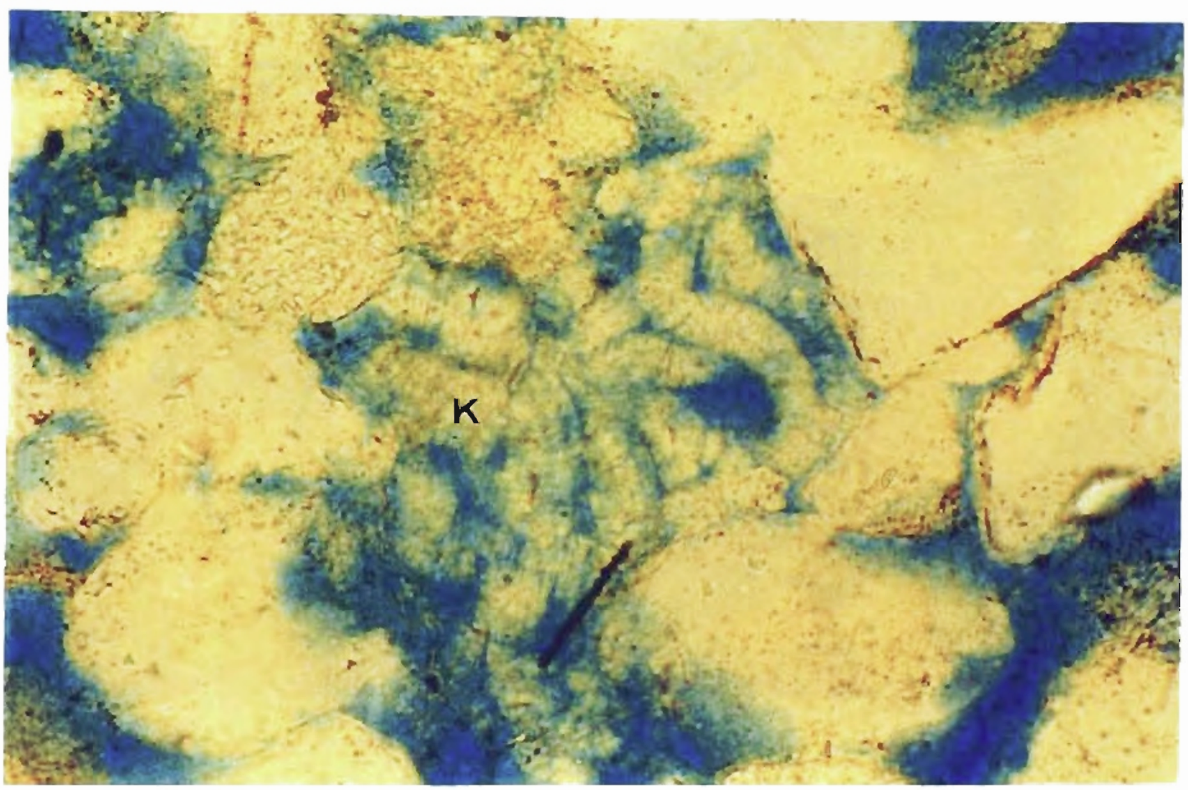


Figure 57. Vermicular kaolinite (K) occluding porosity in the Fortuna sandstone. PPL. 40X.

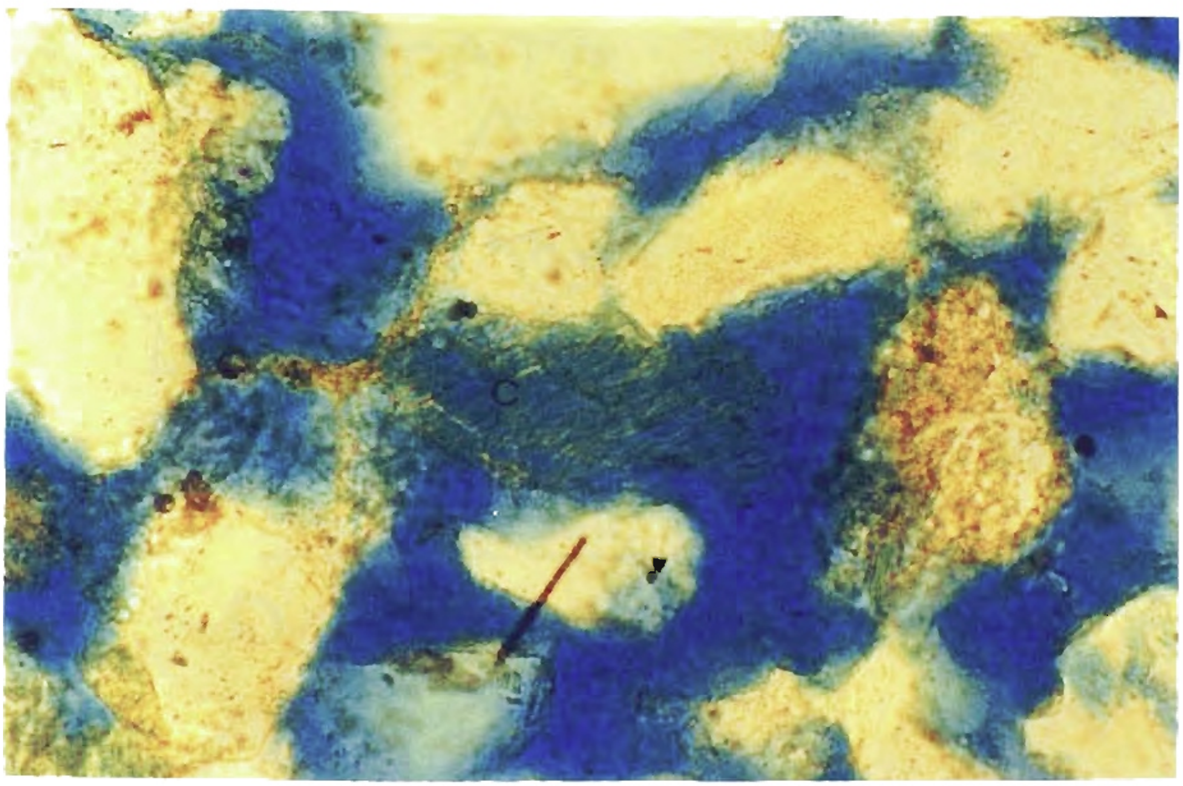


Figure 58. Pore-filling chlorite (C) in the Fortuna sandstone. PPL. 40X.

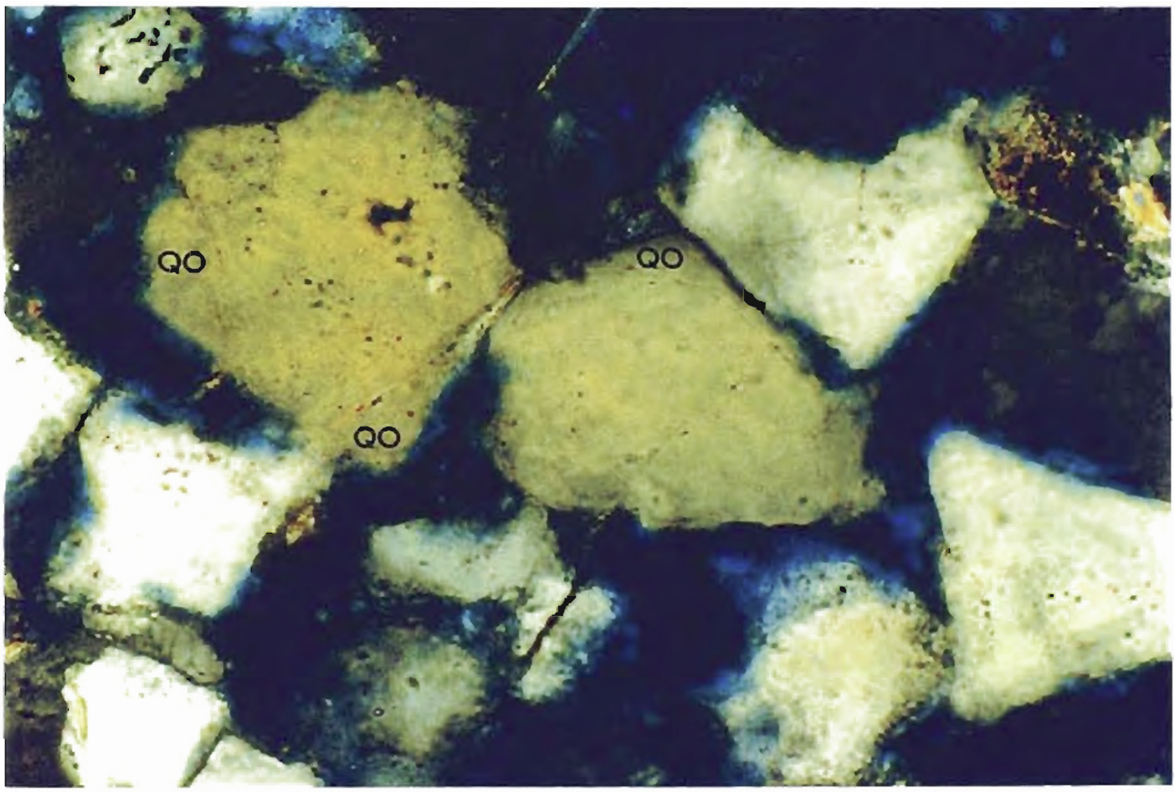


Figure 59. Silica precipitation as quartz-overgrowth cement (QO) in the Fortuna sandstone. XN. 40X.

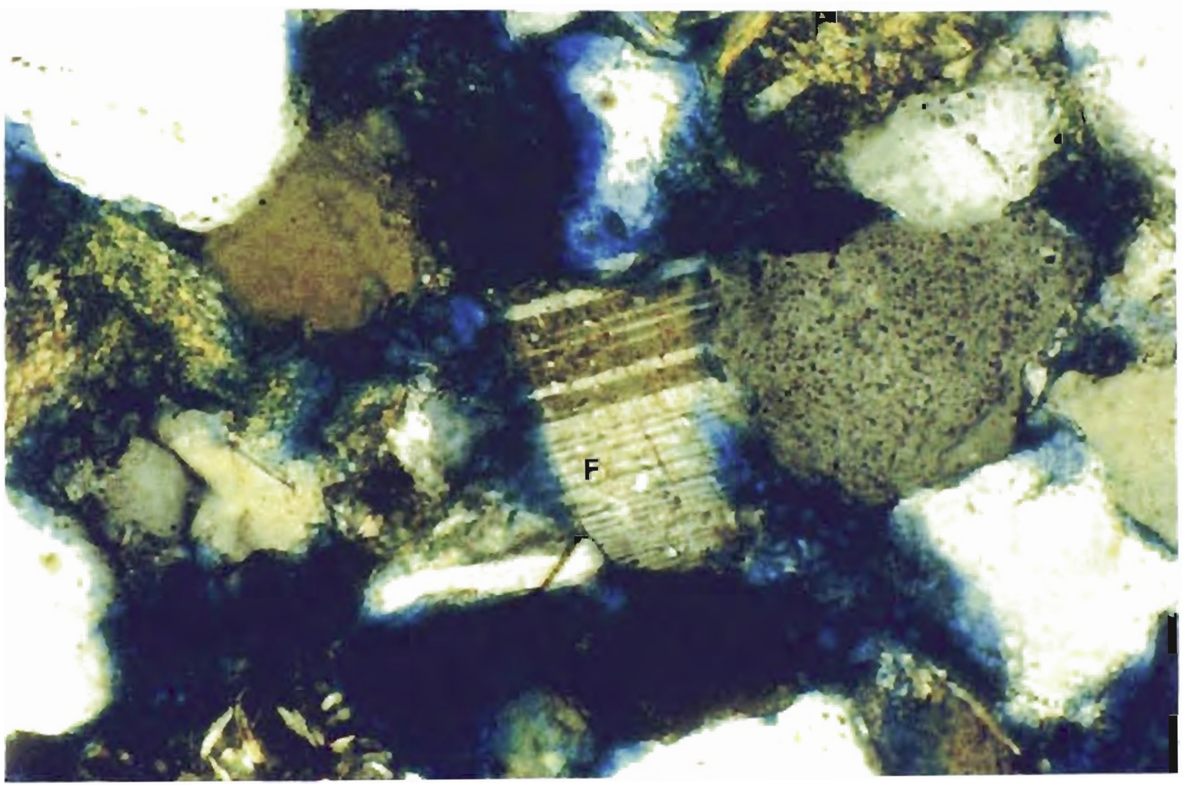


Figure 60. Plagioclase feldspar (F) in the Fortuna sandstone. XN. 40X.

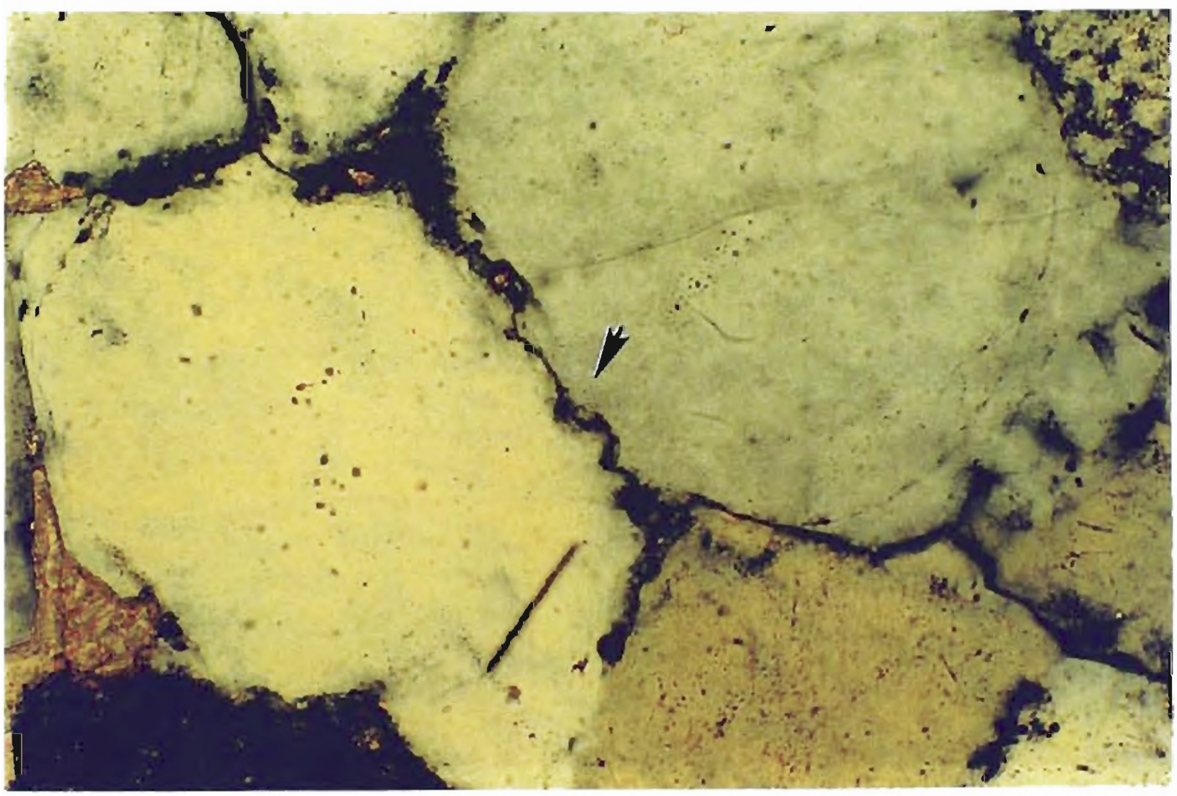


Figure 61. Grain contacts showing grain suturing and penetration (arrow) in the Tonkawa sandstone. XN. 20X.

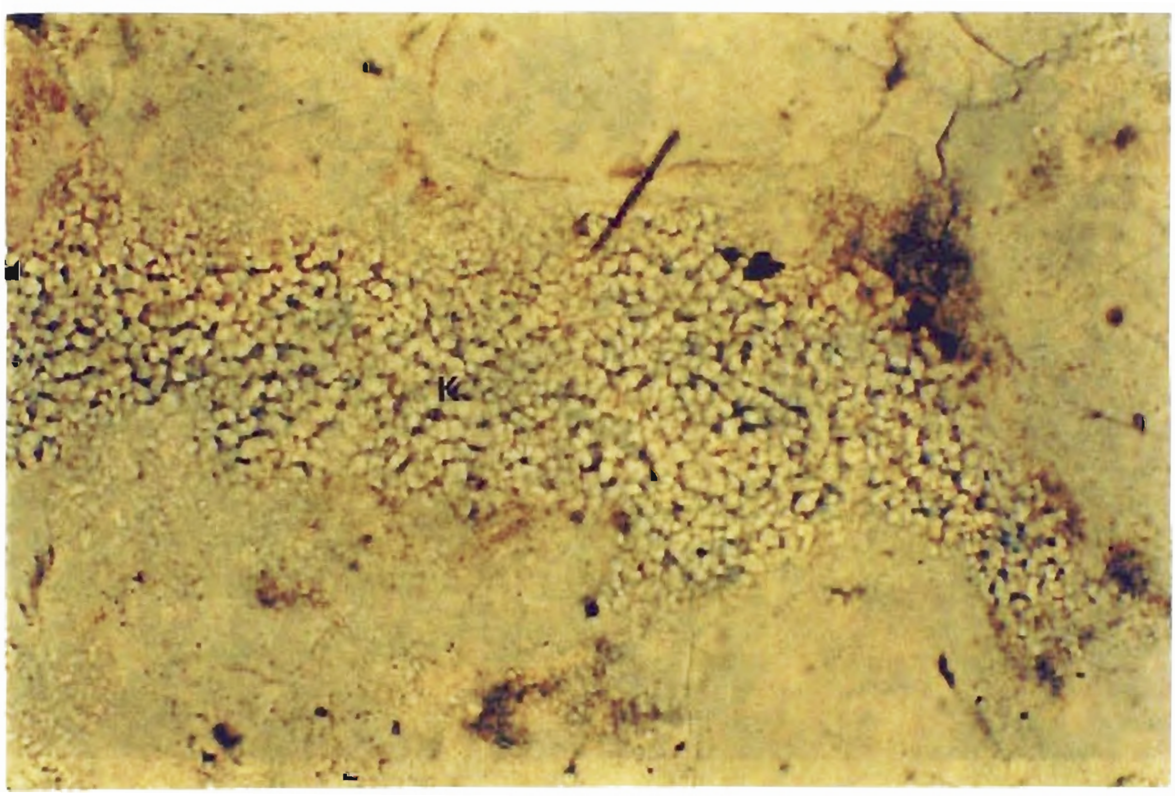


Figure 62. Pore-filling vermicular kaolinite (K) in the Tonkawa sandstone. PPL. 20X.

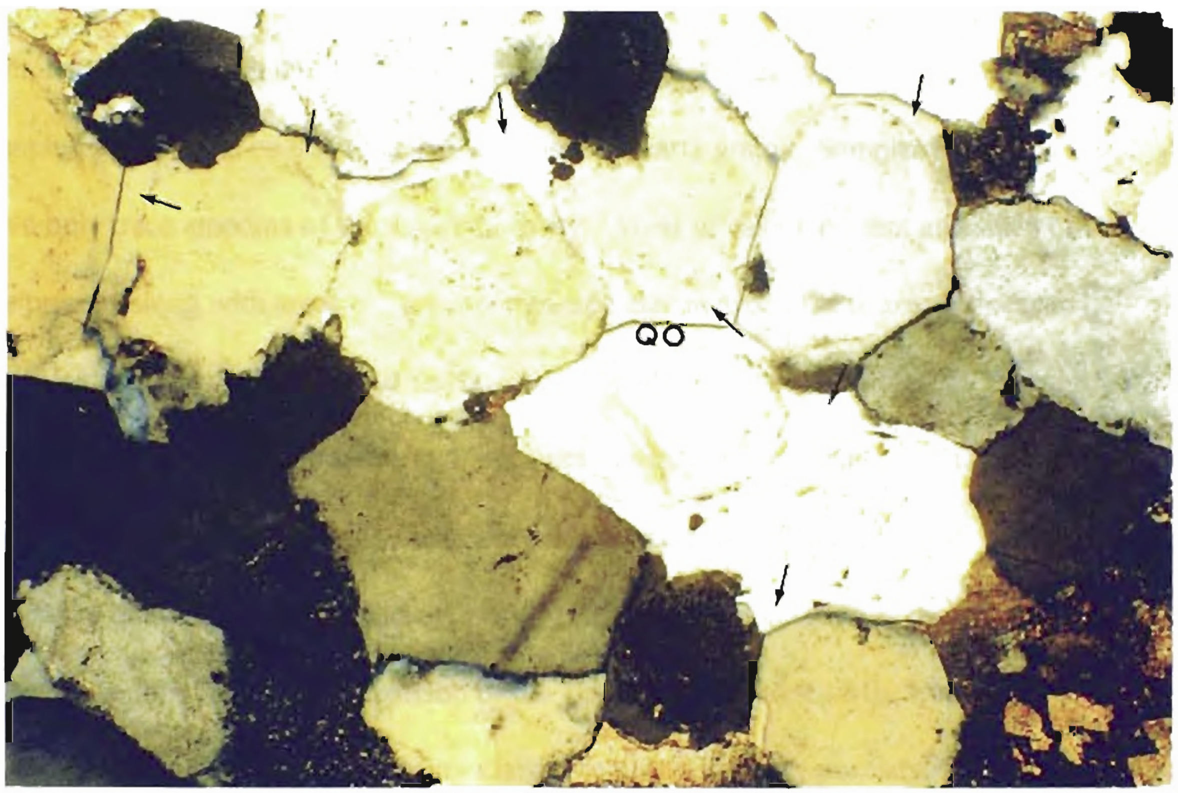


Figure 63. Silica precipitation as quartz-overgrowth cement (QO and arrows) in the Tonkawa sandstone. XN. 10X.

been from (1) an adjacent area where quartz grains underwent dissolution; (2) dissolution of feldspars within the sandstone (Fig. 64); and/or (3) pressure solution dissolution within the sandstone.

Three samples with depths of 8,953, 8,955, and 8,957 feet were viewed. Sample 8,955 is cemented by calcite cement (Fig. 65) containing 0.8 percent secondary porosity. The sample also includes a stylolite that contains insoluble organic material. Tonkawa sample 8,955 contains less silica precipitation and higher silica dissolution than the other samples. This could be due to calcite etching the quartz grains. Samples 8,953 and 8,957 have only trace amounts of secondary porosity. Areas of calcite cement and silica cement are present along with areas of tightly compacted clay matrix. These areas appear to be alternating, cemented bands next to clay matrix bands (Fig 66) Samples 8,953 and 8,957 contain higher silica precipitation and less silica dissolution. The higher silica precipitation is from the cemented bands and the lower silica dissolution is from the matrix rich areas in which the quartz grains were enclosed in clay matrix and inhibited from dissolving

The following is a comparison of the Tonkawa sandstone to the Fortuna sandstone. (1) The Fortuna contains a large amount of primary porosity, whereas the Tonkawa does not contain primary porosity and has only trace to minor amounts of secondary porosity. (2) Clay matrix within the Tonkawa is tightly compacted, whereas clay matrix within the Fortuna is not. (3) Grains within the Tonkawa were slightly to highly compacted. Some Fortuna grains are not in contact and ones that are in contact are only slightly compacted (4) Grain size in the Tonkawa is larger (5) The Fortuna contains no carbonate cement

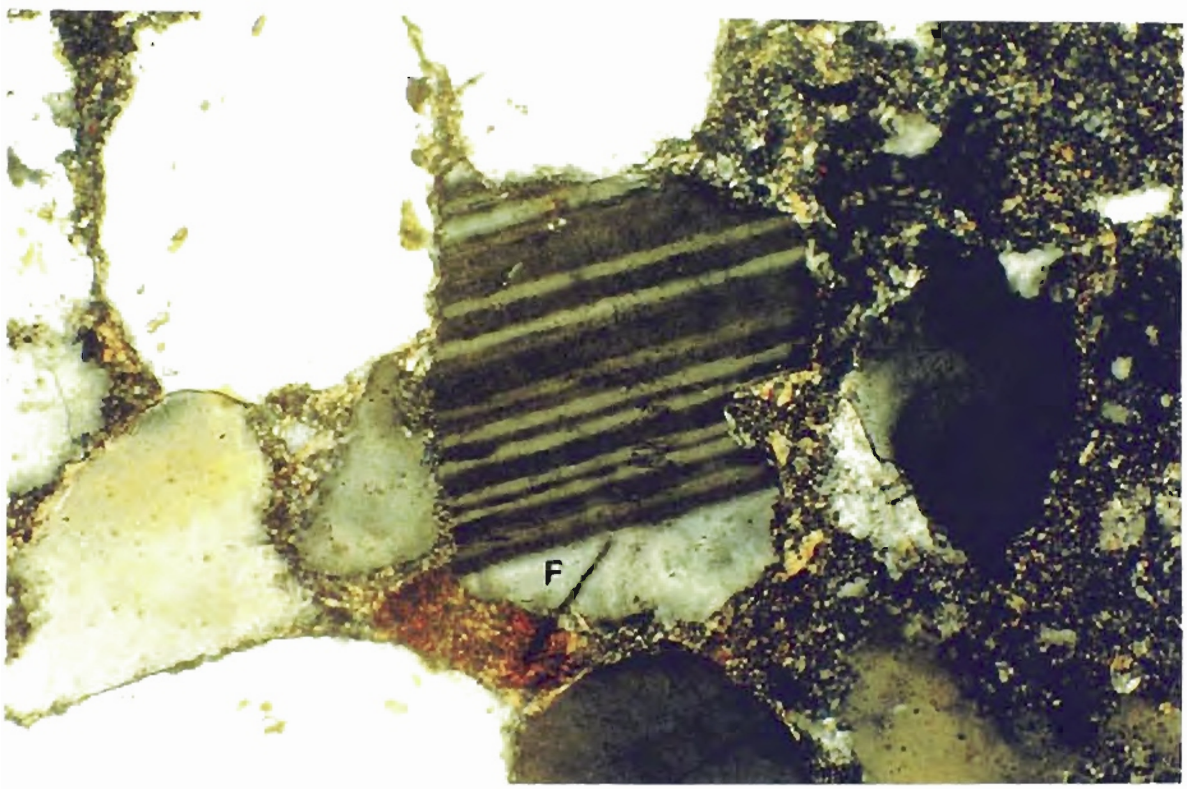


Figure 64. Plagioclase feldspar (F) in the Tonkawa sandstone. XN. 20X.

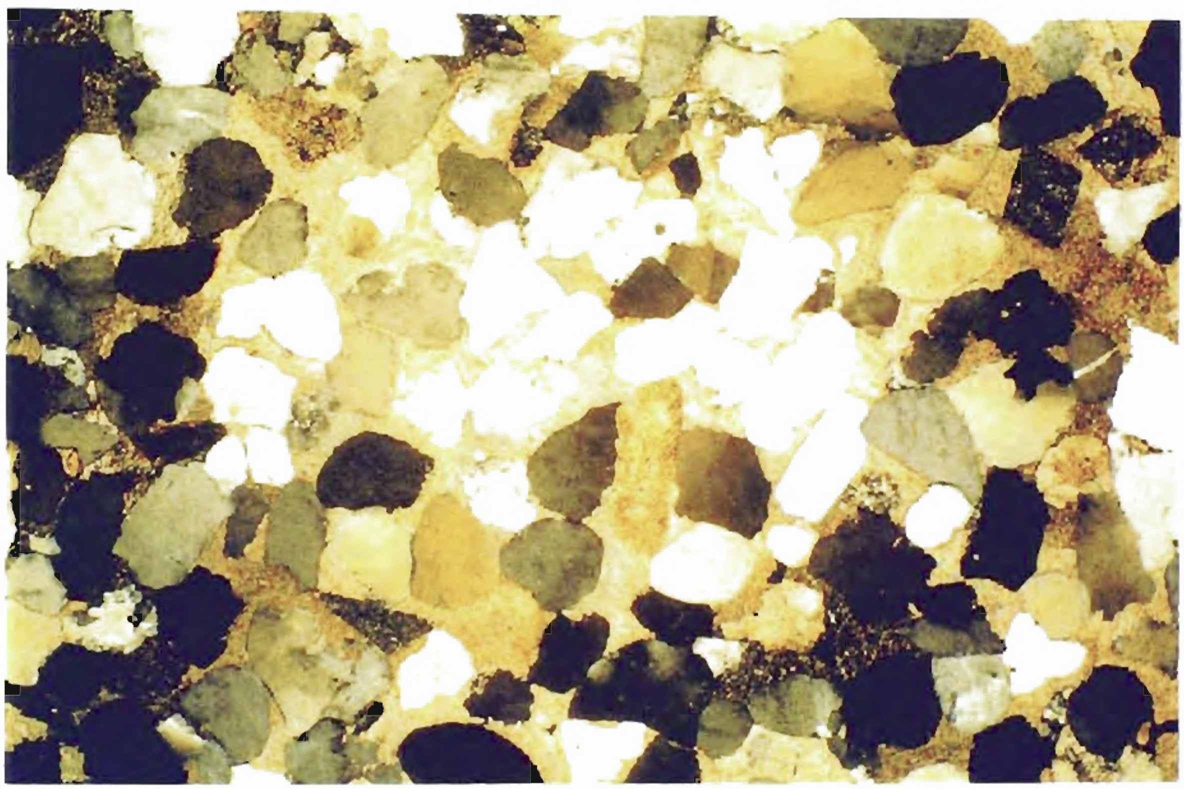


Figure 65. Calcite cement in the Tonkawa sandstone sample 8955. XN. 4X.

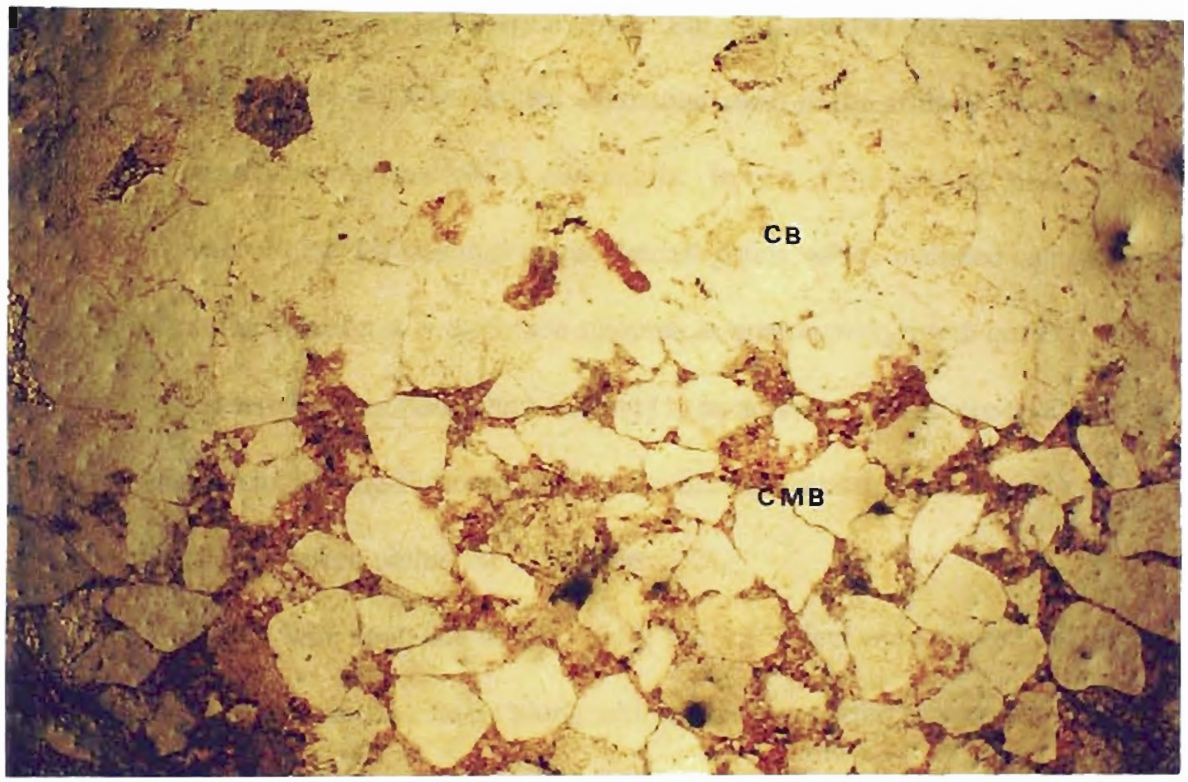


Figure 66. Alternating cemented band (CB) with a clay matrix rich band (CMB) in the Tonkawa sandstone. XN. 4X.

Marchand Sandstone

The Marchand sandstone studied has a depth of 9,855 to 9,958 feet The Marchand sandstone was subjected to compaction as evidenced by (1) grain contact stages 3 to 5, grains were moderately to highly compacted with some grain boundary suturing and penetration (Fig. 67); (2) partial occlusion of primary porosity; (3) formation of pseudomatrix by ductilely deformed detrital grains (Fig. 68), and (4) silica dissolution from quartz-grain pressure solution. In this sandstone, most of the primary porosity was occluded by compaction, cementation, or clay matrix. In two of the samples, primary porosity was preserved by clay coatings on the detrital grains, which inhibited cementation (Fig. 69). Silica precipitation is in moderate amounts as quartz-overgrowth cement. The silica could have been from sources which include (1) an adjacent area where quartz grains underwent dissolution; (2) dissolution of feldspars within the sandstone; and/or (3) pressure-solution dissolution within the sandstone.

Three samples with depths of 9,860, 9,912, and 9,924 feet were viewed. Sample 9,912 contains silica and calcite cement along with tightly compacted clay matrix. It contains a trace amount of secondary porosity. This sample appears to have alternating cement bands next to clay matrix-rich bands. Samples 9,860 and 9,924 contain primary porosity, silica and calcite cement, and no clay matrix.

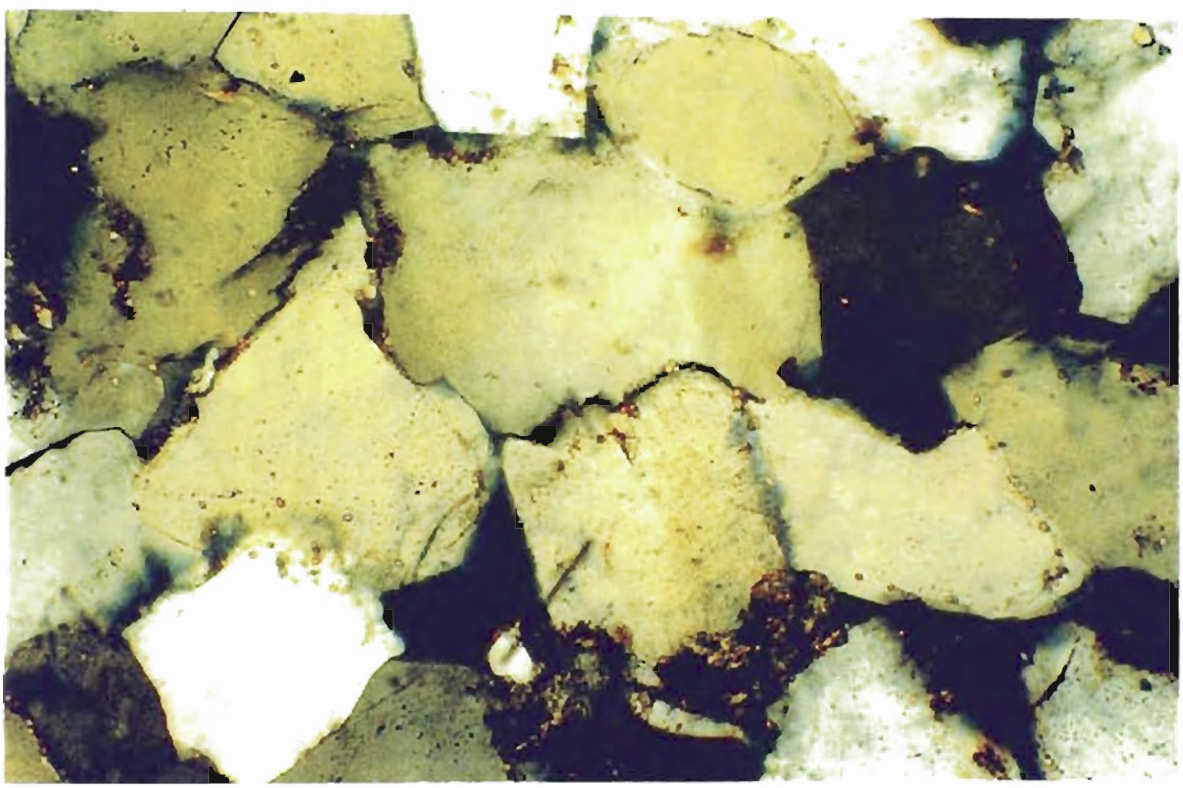


Figure 67. Grain contact stages 3 to 5 in the Marchand sandstone. XN. 20X.

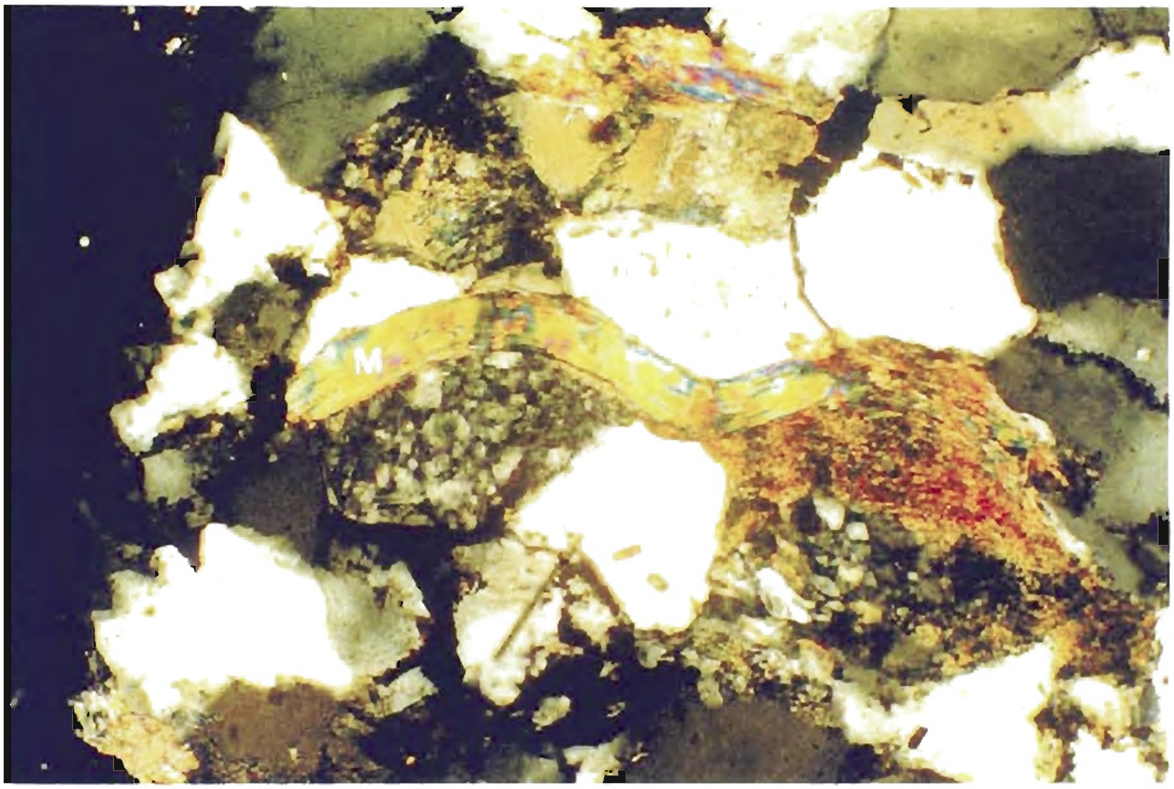


Figure 68. Muscovite grain (M) ductilely deformed in the Marchand sandstone. XN. 20X.

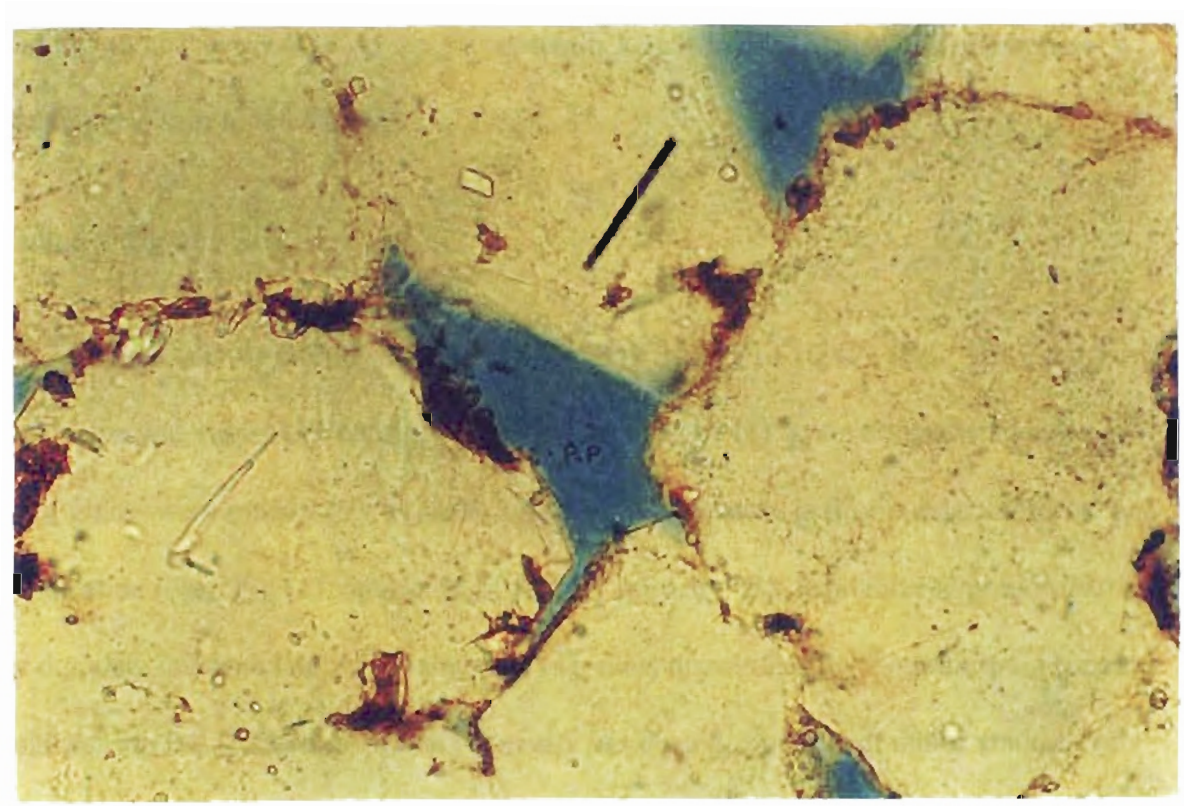


Figure 69. Primary porosity (PP) in the Marchand sandstone. PPL. 40X.

Comparing the Marchand sandstone to the Fortuna sandstone these characteristics are seen: (1) the Marchand contains primary porosity preserved by clay coatings on grains, whereas the Fortuna has primary porosity that was not occluded by compaction (2) Grain size is larger in the Marchand. (3) Grain contacts within the Marchand are in stages 3 to 5, grains were moderately to highly compacted. Fortuna grain contacts are in stages 0 to 2, some grains were not in contact while grains that were in contact were only slightly compacted. (4) Clay matrix content is higher in the Fortuna. (5) Carbonate cement is absent in the Fortuna

Culp Sandstone

The Culp sandstone studied has a depth of 10,388 to 10,421 feet. The Culp sandstone was subjected to compaction as evidenced by (1) grain contact stages 3 to 5, grains were moderately to highly compacted with some grain-boundary suturing and penetration (Fig. 70); (2) occlusion of primary porosity; (3) formation of pseudomatrix by ductilely deformed detrital grains; and (4) silica dissolution from quartz-grain pressure solution. In this sandstone, primary porosity has been occluded, but minor amounts of secondary porosity are present. Primary porosity was occluded by compaction, cementation, and pore-filling clays Secondary porosity was formed by the dissolution of detrital grains or cement. Silica precipitation is in moderate amounts as quartz-overgrowth cement. The silica could have been from sources which include (1) an adjacent area where quartz grains underwent dissolution; (2) dissolution of feldspars within the sandstone, and/or (3) pressure solution dissolution within the sandstone

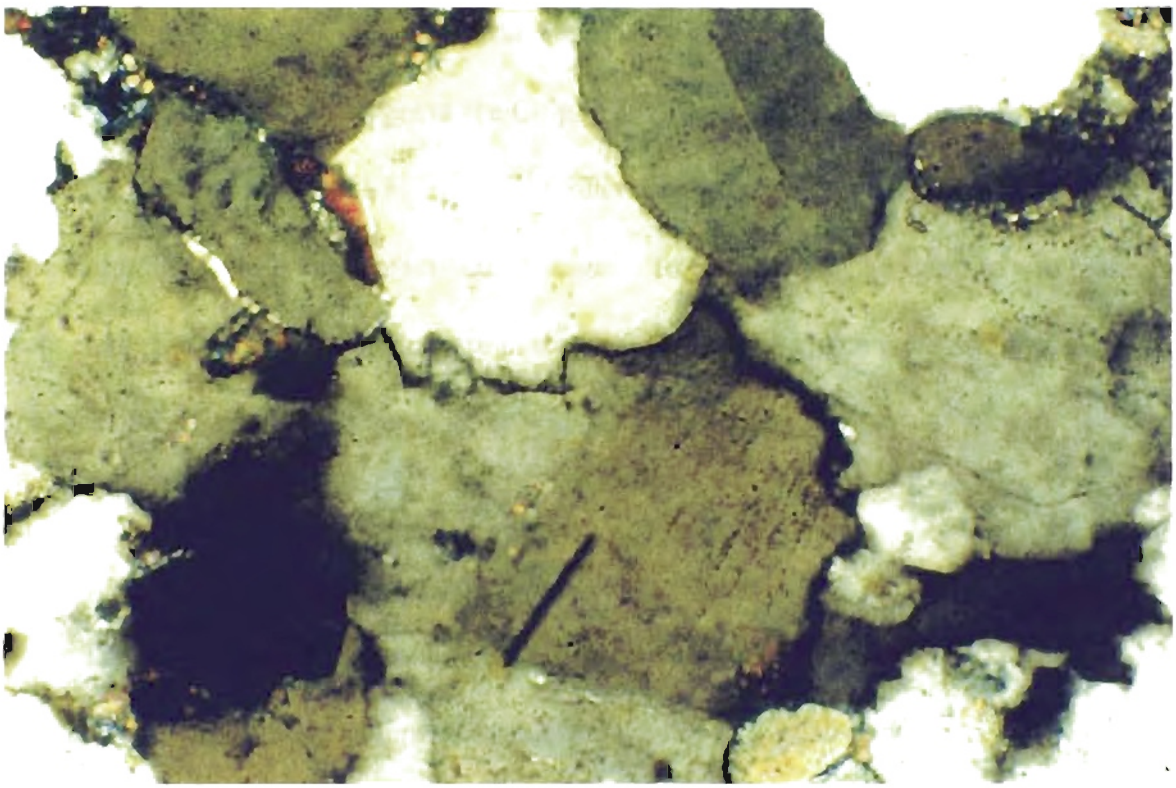


Figure 70. Grain contact stages 3 to 5 in the Culp sandstone. XN. 20X.

Two samples with depths of 10,395 and 10,408 feet were viewed. Both samples are cemented by calcite and silica. Grain size increases with depth and the larger-grained sample (10,395) has less silica dissolution. Larger (coarser) grains have less surface area in contact with other grains than smaller grains, of a similar volume. Therefore, dissolution is less at larger grain-to-grain contacts

Comparing the Culp sandstone to the Fortuna sandstone these characteristics are seen. (1) primary porosity is absent in the Culp whereas in the Fortuna, primary porosity is present. (2) Grain size is larger in the Culp. (3) Clay matrix is absent in the Culp (4) Calcite cement is absent in the Fortuna. (5) Silica precipitation and dissolution are higher in the Culp. (6) Culp grain contacts are in stages 3 to 5, grains were moderately to highly compacted. Fortuna grain contacts are in stages 0 to 2, some grains were not in contact while grains that were in contact were only slightly compacted.

Melton Sandstone

The Melton sandstone studied has a depth of 10,876 to 10,914 feet. The Melton sandstone was subjected to compaction as evidenced by (1) grain contact stages 3 to 5, grains were moderately to highly compacted with some grain-boundary suturing and penetration; (2) occlusion of primary porosity; (3) formation of pseudomatrix by ductilely deformed detrital grains; and (4) silica dissolution from quartz-grain pressure solution. Primary porosity was occluded by compaction, cementation, and pore-filling clays (Fig. 71). Secondary porosity was formed by the dissolution of cementing material Silica precipitation is in moderate amounts as quartz-overgrowth cement. Silica could

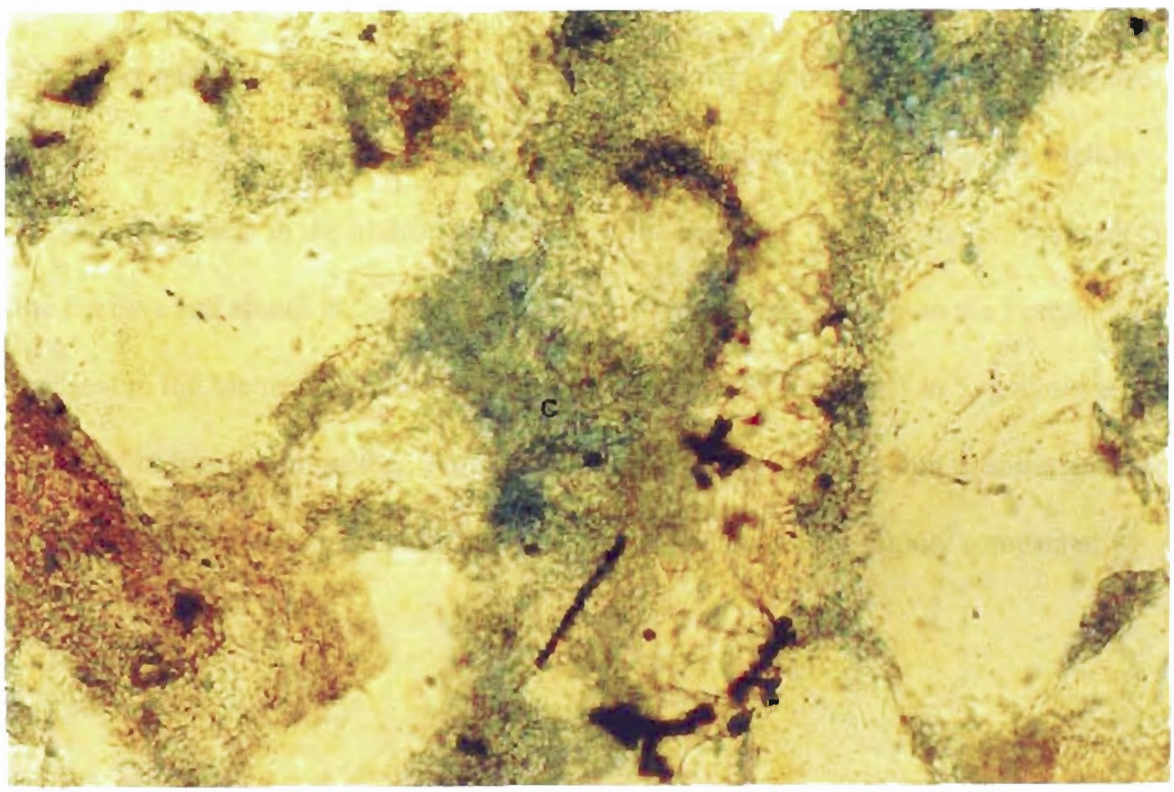


Figure 71. Pore-filling chlorite (C) in the Melton sandstone. PPL. 40X.

have been from sources which include (1) an adjacent area where quartz grains underwent dissolution; (2) dissolution of feldspars within the sandstone; and/or (3) pressure solution dissolution within the sandstone.

One sample with a depth of 10,878 feet was viewed. This sample is cemented by silica and calcite and has trace amounts of secondary porosity.

The following is a comparison of the Melton sandstone and the Fortuna sandstone: (1) burial compaction is more extensive in the Melton than in the Fortuna. (2) Grain size of the Fortuna is smaller. (3) Silica precipitation and dissolution are higher in the Melton. (4) Calcite is present in the Melton and absent in the Fortuna. (5) Clay matrix is present in the Fortuna and absent in the Melton. (6) Primary porosity is present in the Fortuna and absent in the Melton. (7) The Melton grain contacts are in stages 3 to 5, grains were moderately to highly compacted. Fortuna grain contacts are in stages 0 to 2, some grains were not in contact while grains that were in contact had been only slightly compacted.

Deep Burial Depth

Red Fork Sandstone

The Red Fork sandstone studied has a depth of 14,055 to 14,119 feet. The Red Fork sandstone was subjected to compaction as evidenced by (1) occlusion of primary porosity; (2) formation of pseudomatrix by ductilely deformed detrital grains; and (3) tightly compacted clay matrix (Fig. 72). Primary porosity was occluded and secondary porosity is in trace amounts to 1 percent. Primary porosity was occluded by the compaction of the detrital clay matrix between the grains (Fig. 73)

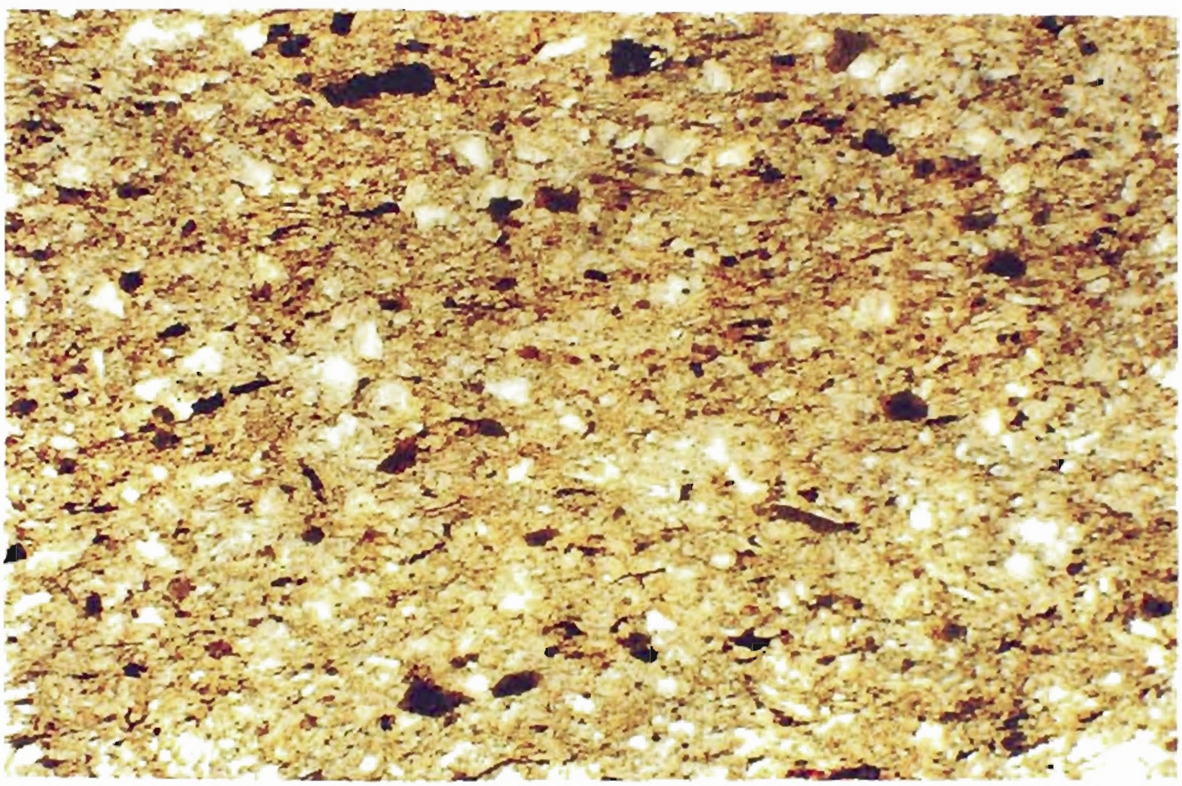


Figure 72. Detrital clay-matrix in the Red Fork sandstone. PPL. 20X.

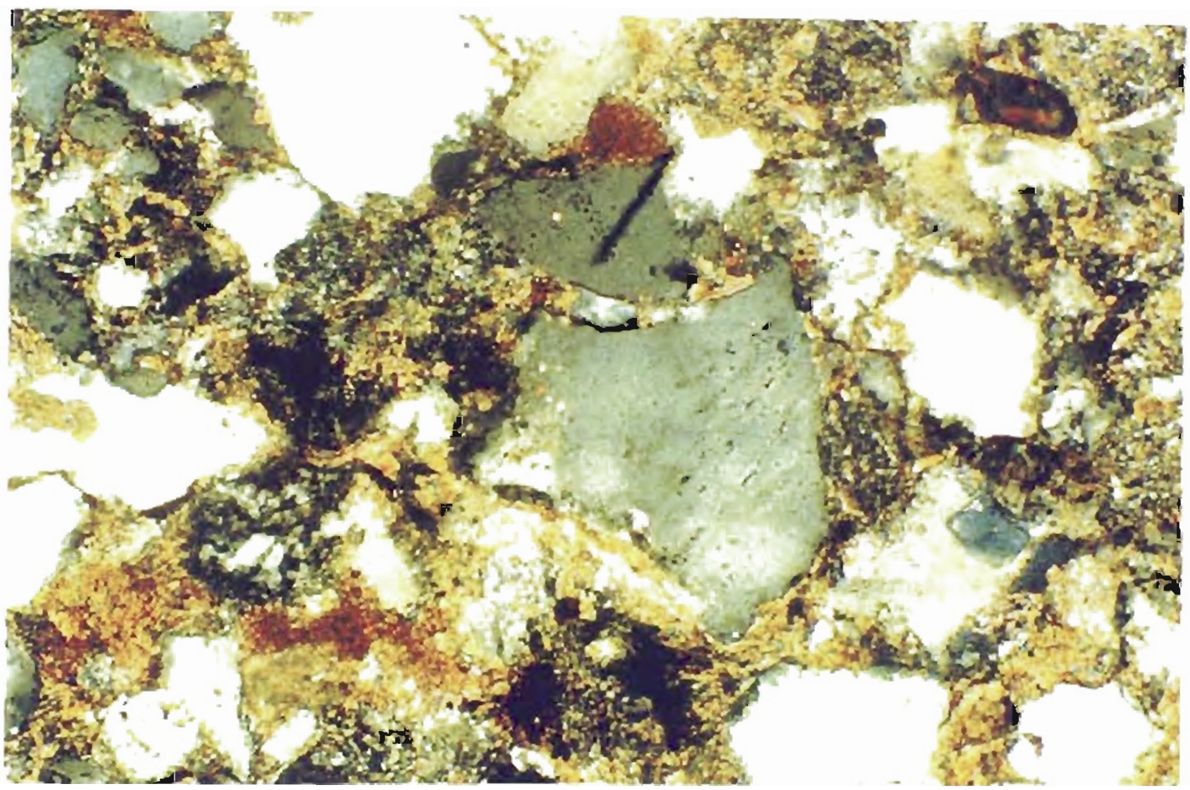


Figure 73. Occlusion of the primary porosity by compaction of detrital clay-matrix between the quartz grains in the Red Fork sandstone. XN. 20X.

Minor to moderate amounts of silica precipitation occurred as quartz-overgrowth cement. The silica could have been from an adjacent area where quartz grains underwent dissolution and/or dissolution of feldspars within the sandstone

Seven samples from depths ranging from 14,098 to 14,147 feet were viewed. Sample 14,098 contains stylolites, which were filled with organic material (Fig. 74) Samples with higher clay matrix content generally have less silica precipitation and dissolution. Compaction of the detrital matrix occluded primary porosity and allowed only minor cementation.

Comparison of the Red Fork sandstone to the intermediate sandstones (Tonkawa, Marchand, Culp, and Melton). (1) the Red Fork clay matrix is extensive whereas the Tonkawa and Marchand samples contain clay matrix only in small areas of the sample. (2) Silica precipitation in the Red Fork is lower. (3) Grain size in the Red Fork is smaller. (4) Primary porosity is absent in the Red Fork, Tonkawa, Culp, and Melton but present in the Marchand. (5) The Culp and Melton sandstones have larger volumes of secondary porosity than the Red Fork.

Comparison of the Red Fork sandstone to the Fortuna sandstone: (1) the Red Fork has been subjected to compaction causing the clay matrix to compact between the grains and occlude primary porosity. The Fortuna was slightly compacted. Clay matrix was not tightly compacted between quartz grains and did not occlude primary porosity. (2) Primary porosity is absent in the Red Fork but present in the Fortuna. (3) The Red Fork has trace to minor amounts of calcite cement, whereas the Fortuna contains no calcite cement. (4) Grain sizes are smaller in the Red Fork than the Fortuna

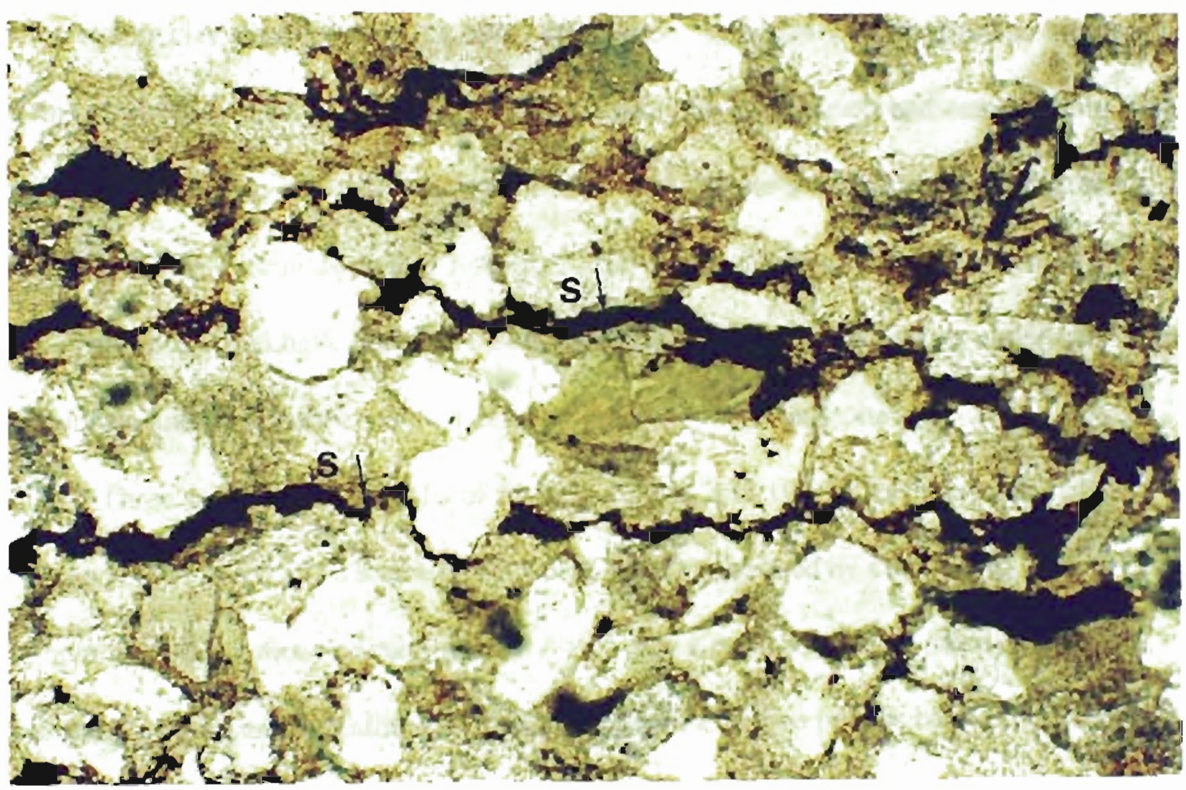


Figure 74. Stylolites (S) filled with organic material in the Red Fork sandstone. PPL. 20X.

Springer Sandstone

The Springer sandstone studied is from a depth of 10,891 to 10,921 feet. The Springer sandstone was subjected to compaction as evidenced by (1) grain contact stages 3 to 5, grains were moderately to highly compacted with some grain boundary suturing and penetration (Fig. 75); (2) occlusion of primary porosity; except where it has been preserved by clay coatings; and (3) silica dissolution from quartz-grain pressure solution. In this sandstone, most of the porosity was occluded by compaction and cementation. The primary porosity that is remaining was preserved by chlorite's coating of detrital grains (Fig. 76). Silica precipitation is in moderate amounts as quartz-overgrowth cement (Fig 77). The silica could have been from an adjacent area where quartz grains underwent dissolution and/or pressure solution dissolution within the sandstone

Three samples from depths of 10,901, 10,906, and 10,912 feet were studied. Sample 10,901 has the lower primary porosity and is cemented by calcite (Fig. 78). Sample 10,906 has more primary porosity with only a trace amount of calcite cement. The sample contains alternating silica-cemented bands next to porous bands (Fig. 79) This sample contains stylolites which were filled with organic material (Fig. 80). Sample 10,912 has the highest volume of preserved porosity and also contains alternating silica-cemented bands next to porous bands. This sample also contains a stylolite filled with organic material. The coarser-grained samples (10,901 and 10,912) have less silica dissolution than the finer-grained sample. This could be because larger grains have less surface area in contact, therefore, dissolution is less

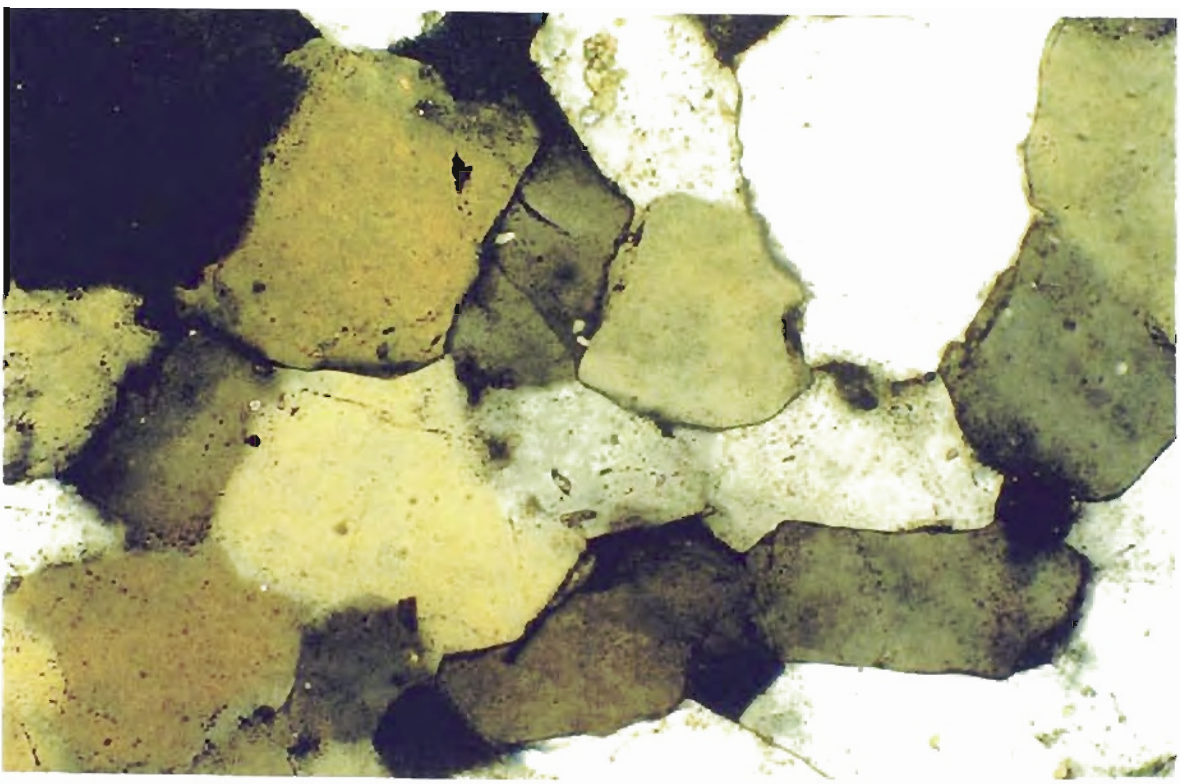


Figure 75. Grain contact stages 3 to 5 in the Springer sandstone. XN. 20X.

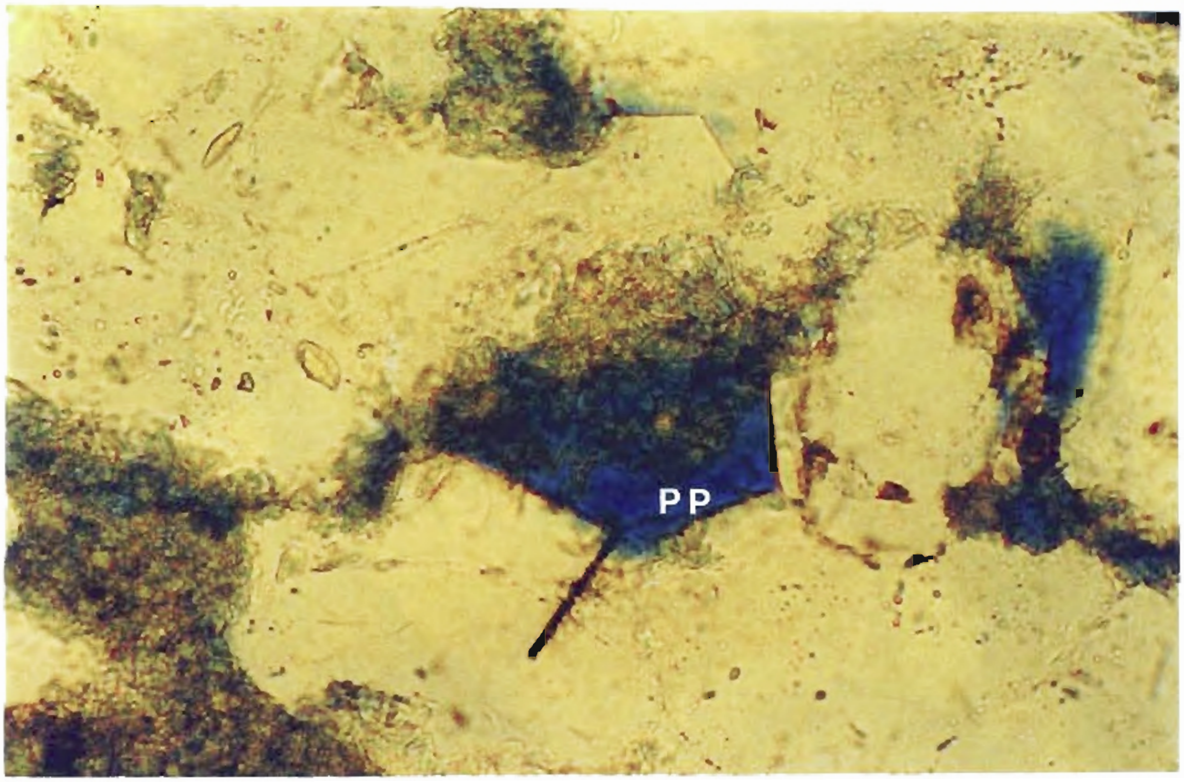


Figure 76. Primary porosity (PP) in the Springer sandstone. PPL. 40X.

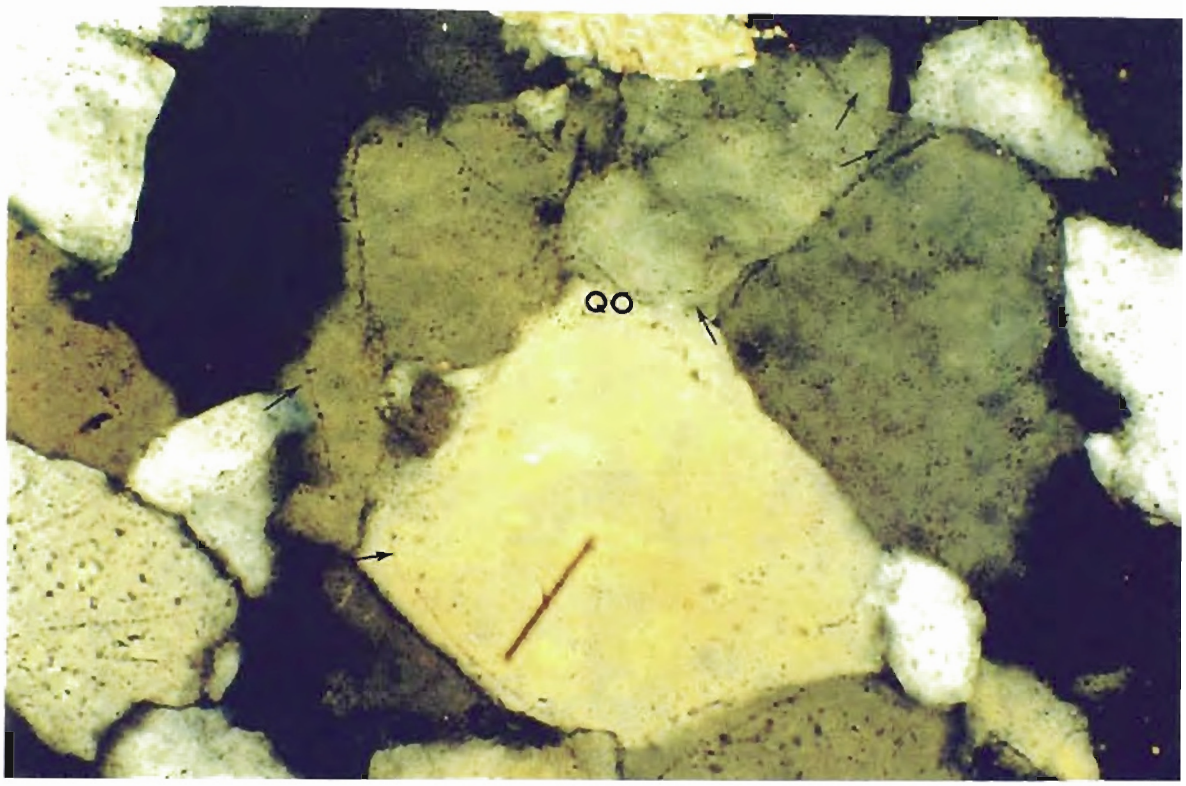


Figure 77. Silica precipitation as quartz-overgrowth cement (QO and arrows) in the Springer sandstone. XN. 20X.

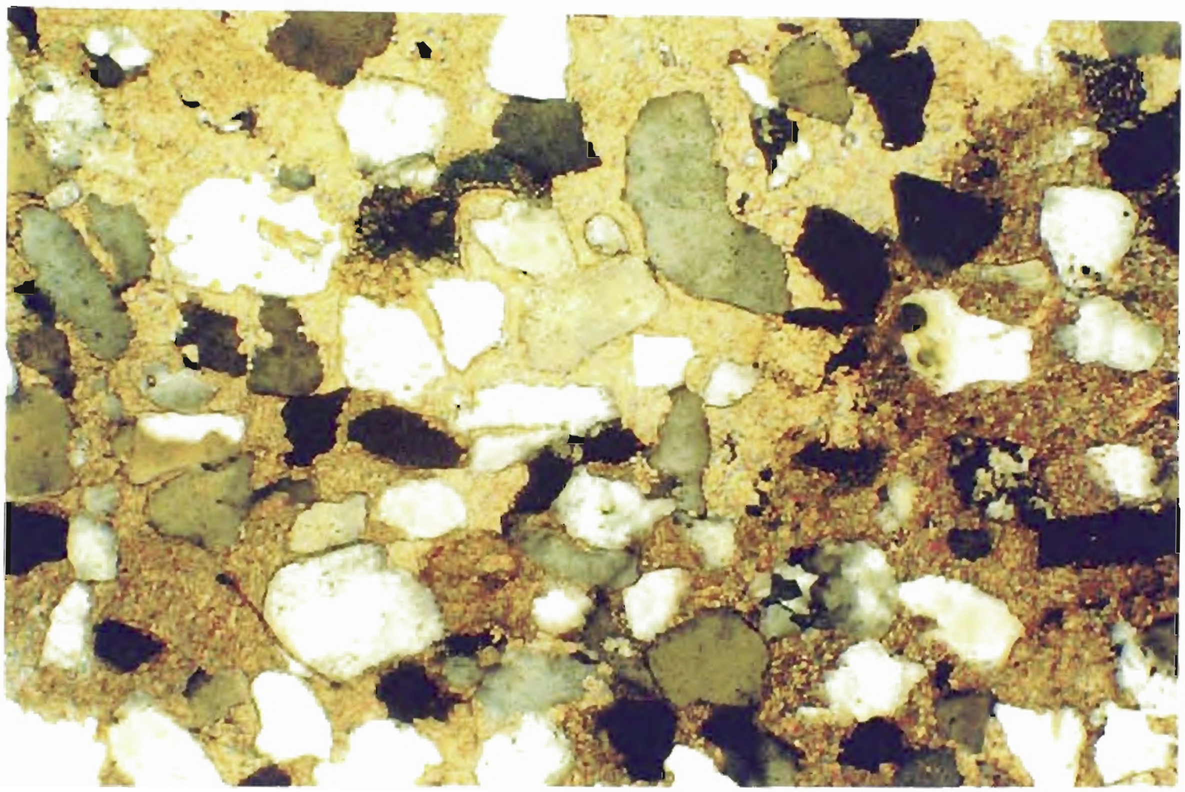


Figure 78 Calcite cement in the Springer sandstone sample 10,901. XN. 10X.

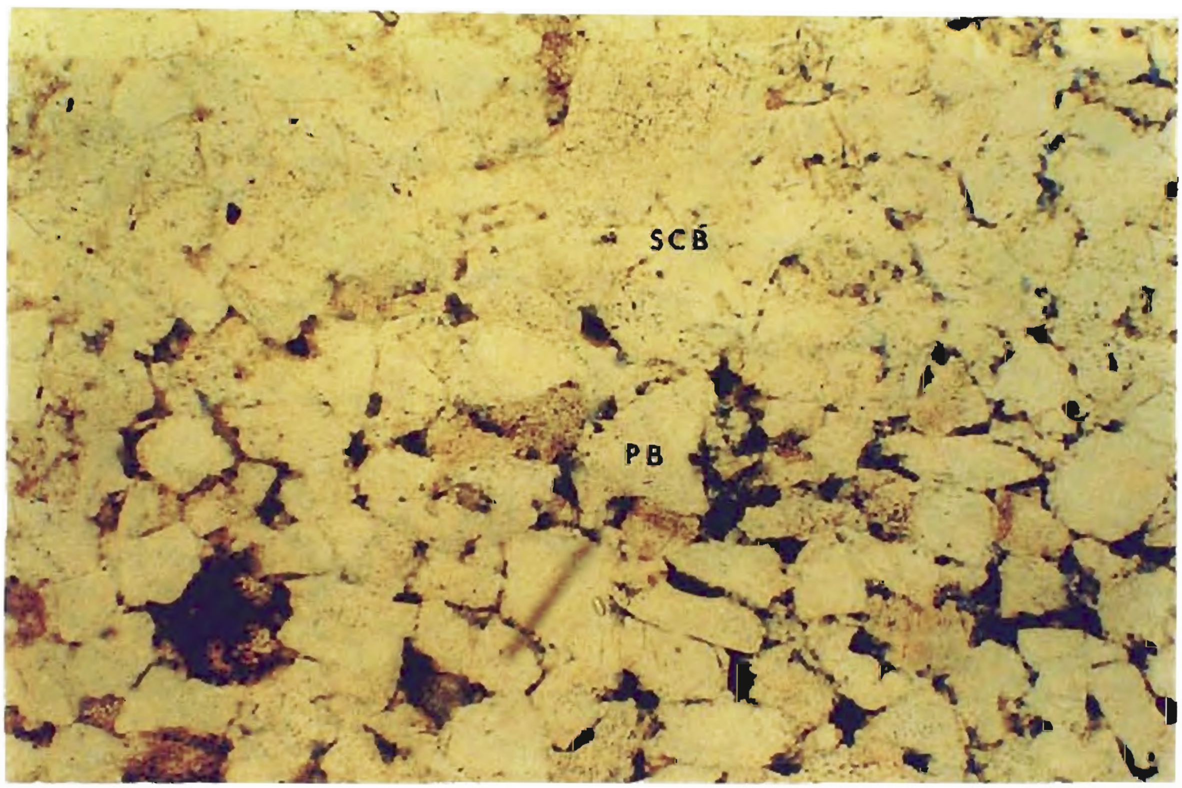


Figure 79. Alternating silica-cemented band (SCB) with a porous band (PB) in the Springer sandstone. PPL. 10X.

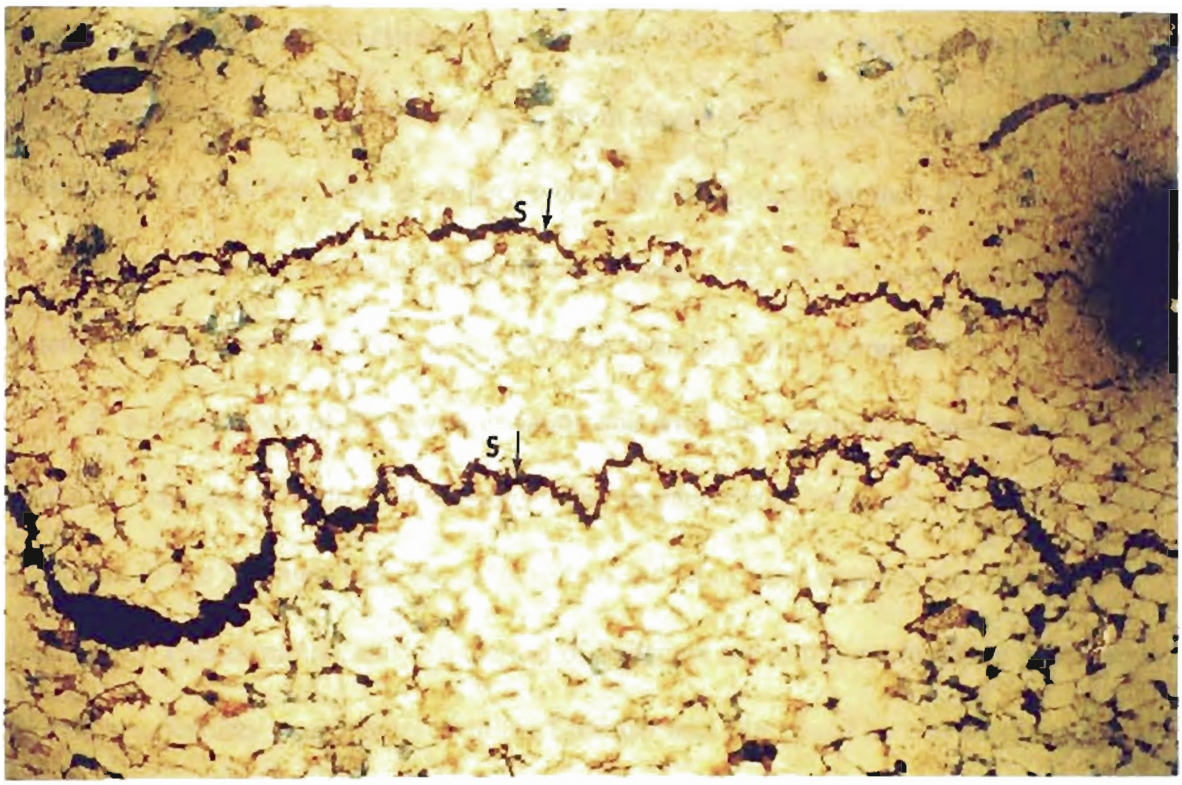


Figure 80. Stylolites (S) filled with organic material in the Springer sandstone. PPL. 4X.

In comparison of the Springer sandstone to the Fortuna sandstone these characteristics were noted: (1) the Springer had been subjected to extensive compaction whereas the Fortuna has only been slightly compacted. (2) Clay matrix is absent in the Springer. (3) Primary porosity has been preserved in the Springer by clay coatings on detrital grains, whereas in the Fortuna, the slight compaction did not occlude the primary porosity (4) Calcite cement is absent in the Fortuna. (5) Pseudomatrix is present in the Fortuna. (6) Springer grain contacts are in stages 3 to 5, grains were moderately to highly compacted. Fortuna grain contacts are in stages 0 to 2, some grains were not in contact while grains that were in contact were only slightly compacted. (7) Silica precipitation and dissolution are higher in the Springer. (8) The Springer contains diagenetic features of alternating silica-cemented bands next to porous bands.

In a comparison of the Springer sandstone with the intermediate sandstones (Tonkawa, Marchand, Culp, and Melton) these characteristics were seen: (1) clay matrix was absent in the Springer whereas in Tonkawa and Marchand samples clay matrix is present. (2) Pseudomatrix and dissolution of feldspars are in the intermediate sandstones. (3) Primary porosity was preserved in the Springer and Marchand by clay coatings on the detrital grains. (4) Calcite cement and silica cement are present in all of the sandstones. (5) The Springer has alternating silica-cemented bands next to porous bands whereas the Tonkawa has alternating cemented bands next to clay matrix rich bands

Bromide Sandstone

The Bromide sandstone studied has a depth of 13,362 to 13,421 feet. The Bromide sandstone was subjected to compaction as evidenced by (1) grain contact stages 3 to 5, grains were moderately to highly compacted with some grain-boundary suturing and penetration (Fig. 81); (2) occlusion of primary porosity, except where it has been preserved by clay coatings on detrital grains; and (3) silica dissolution from quartz- grain pressure solution. In this sandstone, the primary porosity was occluded by compaction and cementation. Silica precipitation is in moderate amounts as quartz overgrowth cement (Fig. 82). The silica could have been from an adjacent area where quartz grains underwent dissolution and/or pressure solution dissolution within the sandstone

Three samples from depths of 13,375, 13,389, and 13,408 feet were studied. Sample 13,375 contains minor secondary porosity and is calcite cemented (Fig. 83) Sample 13,389 is dolomite cemented with minor amounts of silica and calcite cement. This sample contains a stylolite filled with organic material (Fig. 84). Sample 13,408 contains minor amounts of primary porosity preserved by clay coatings on detrital grains and has alternating silica-cemented bands next to porous bands (Fig. 85).

In comparison of the Bromide sandstone to the Fortuna sandstone these characteristics were noted: (1) the Bromide was subjected to extensive compaction whereas the Fortuna has only been slightly compacted. (2) Clay matrix is absent in the Bromide (3) Primary porosity has been preserved in the Bromide by clay coatings on grains and in the Fortuna primary porosity was not occluded by compaction. (4) Calcite and dolomite cements are absent in the Fortuna. (5) Pseudomatrix is present in the

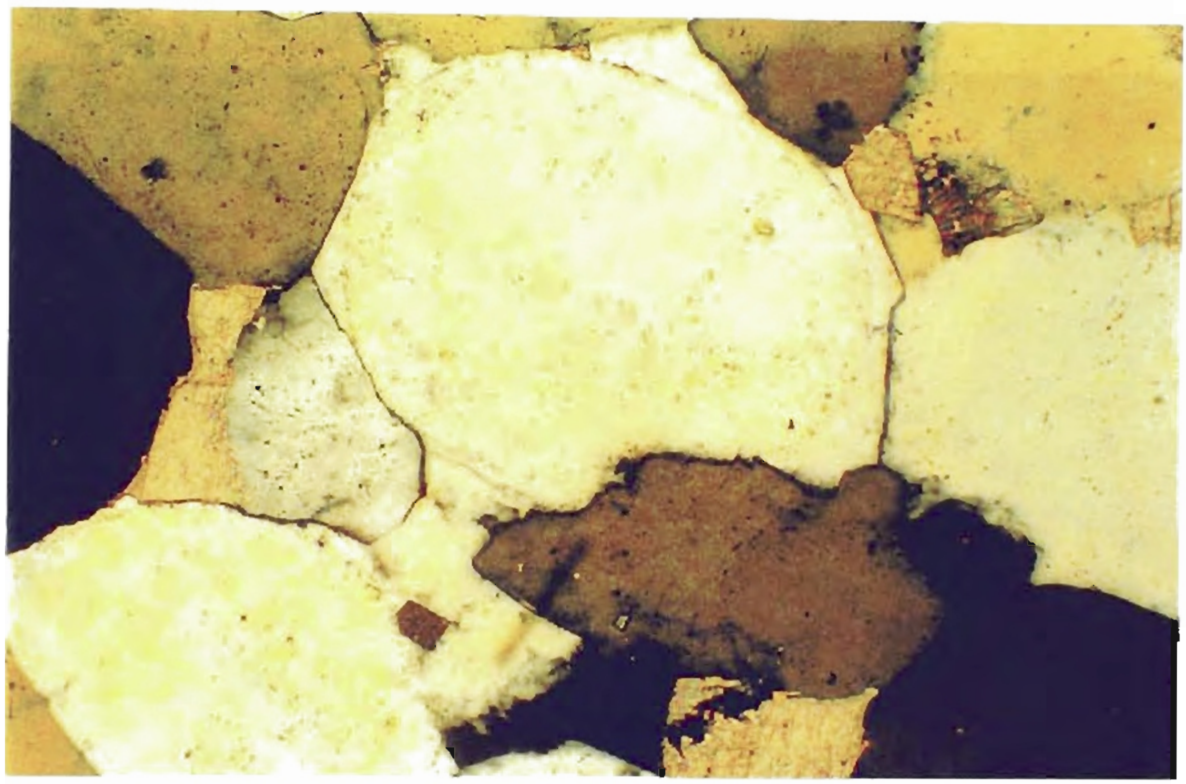


Figure 81. Grain contact stages 3 to 5 in the Bromide sandstone. XN. 10X.

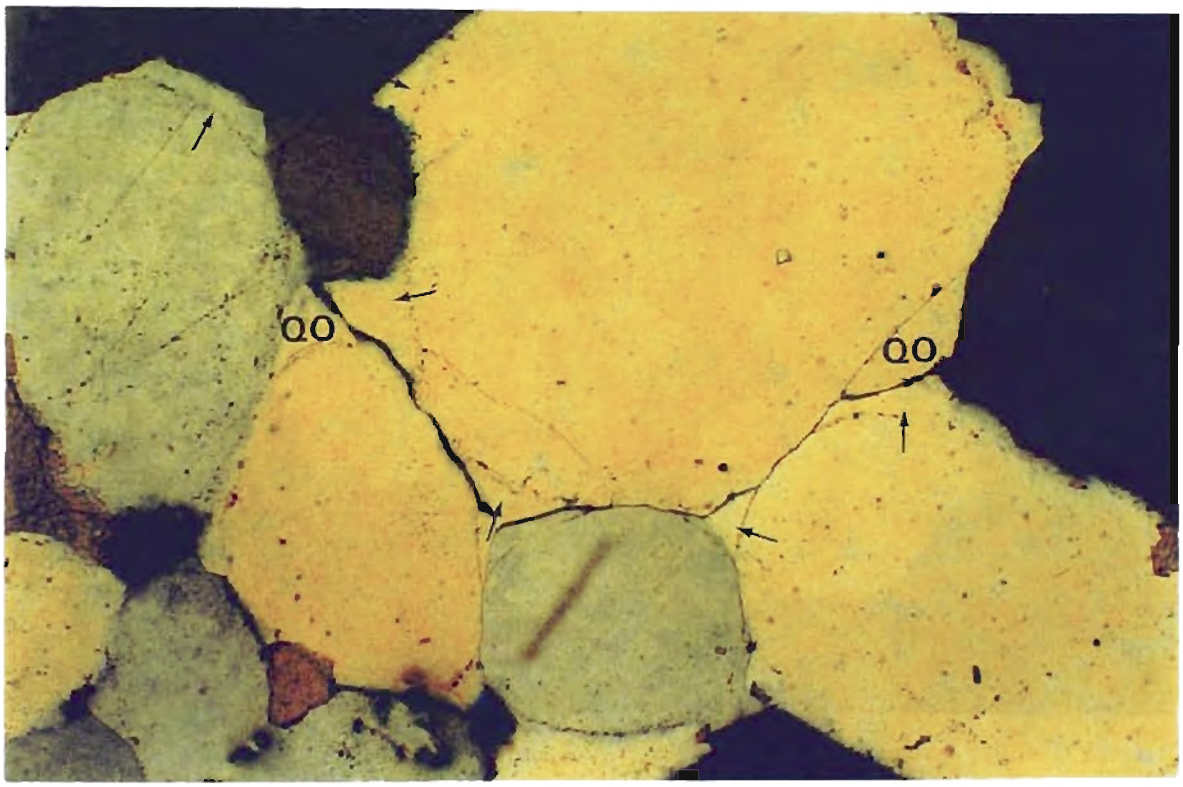


Figure 82. Silica precipitation as quartz-overgrowth cement (QO and arrows) in the Bromide sandstone. XN. 10X.

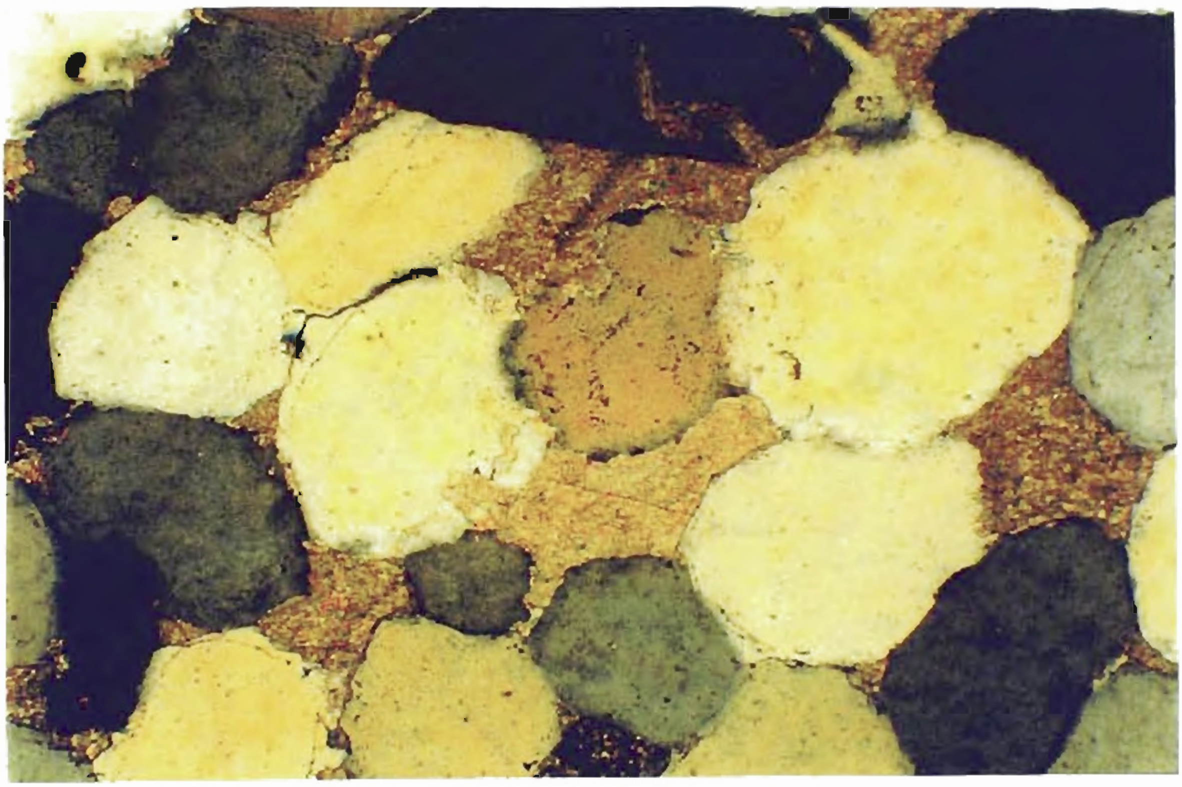


Figure 83. Calcite cement in the Bromide sandstone sample 13.375. XN. 10X.

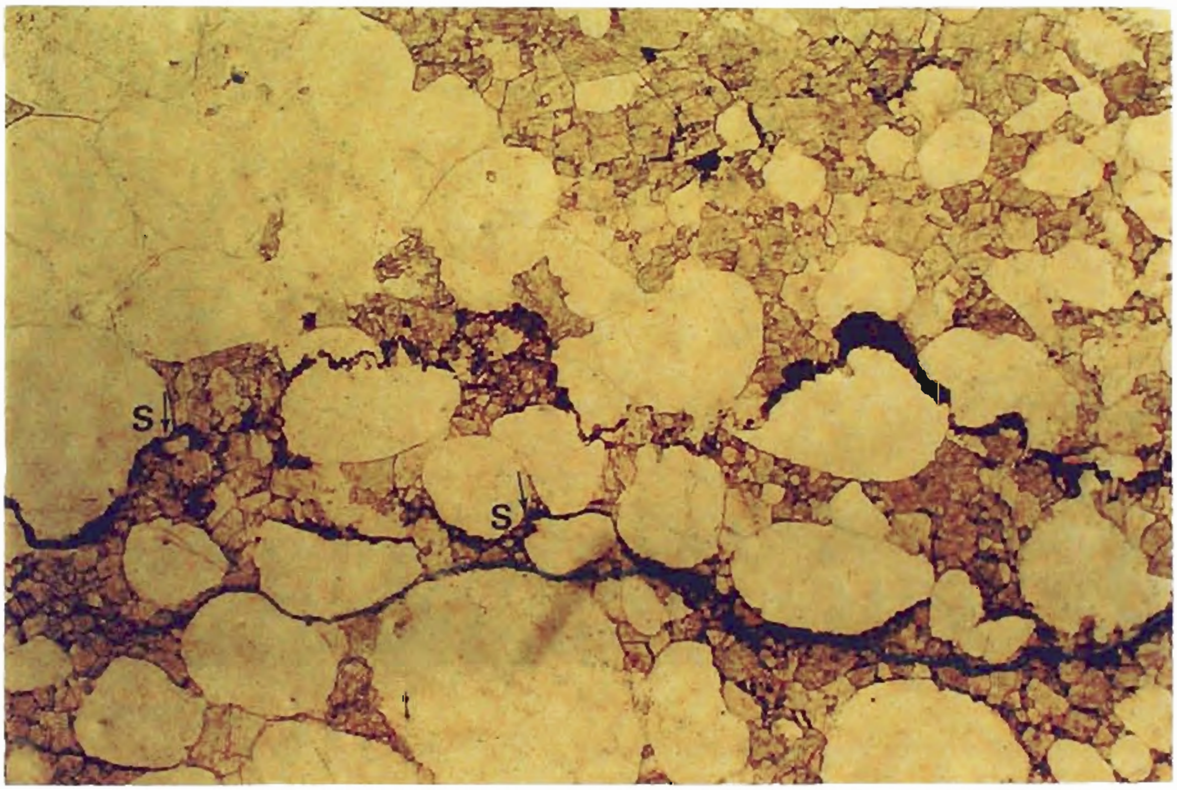


Figure 84. Stylolites (S) filled with organic material in the Bromide sandstone. PPL. 4X.

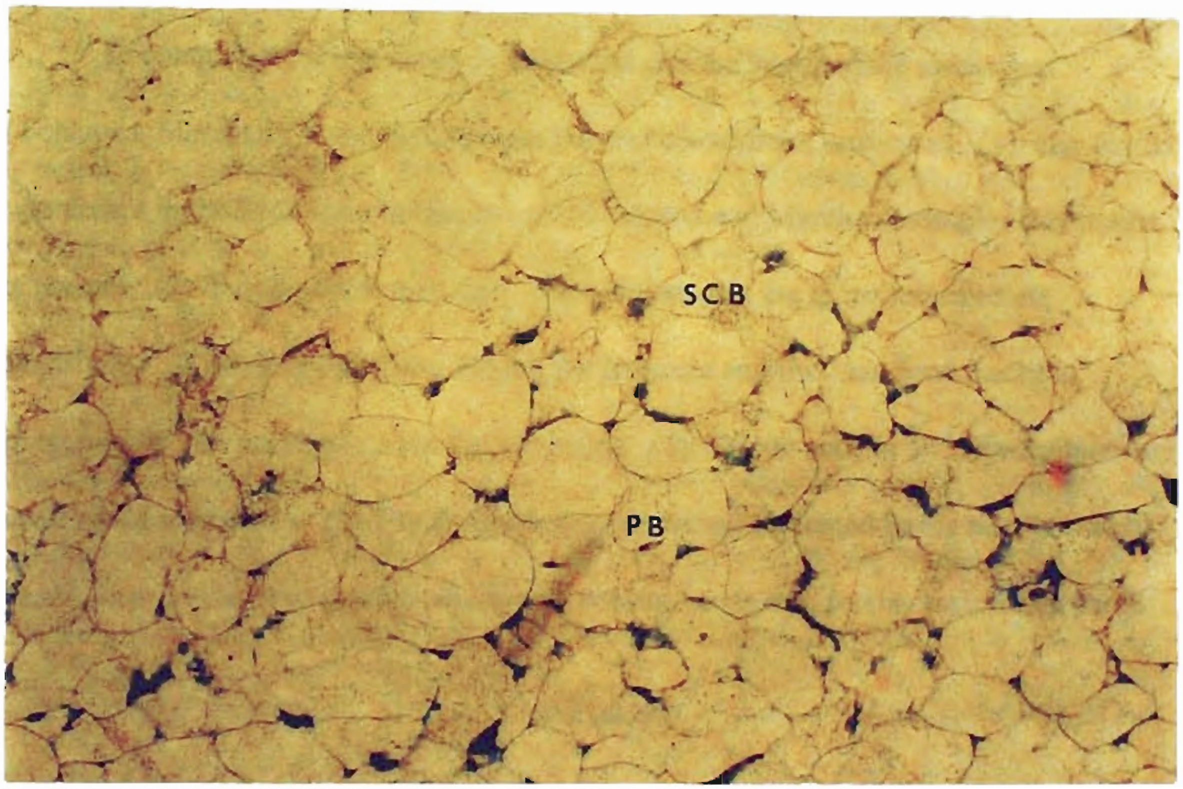


Figure 85. Alternating silica-cemented band (SCB) with a porous band (PB) in the Bromide sandstone. PPL. 4X.

Fortuna. (6) Bromide grain contacts are in stages 3 to 5, grains were moderately to highly compacted. Fortuna grain contacts are in stages 0 to 2, some grains were not in contact while grains that were in contact were only slightly compacted. (7) Silica precipitation and dissolution are higher in the Bromide. (8) The Bromide contains alternating silica-cemented bands next to porous bands.

In comparison of the Bromide sandstone and the intermediate sandstones (Tonkawa, Marchand, Culp, and Melton) these characteristics were seen (1) clay matrix was absent in the Bromide whereas in some Tonkawa and Marchand samples clay matrix is present. (2) Pseudomatrix and dissolution of feldspars are in the intermediate sandstones. (3) Primary porosity in both the Bromide and the Marchand has been preserved by clay coatings on the detrital grains. (4) Calcite cement and silica cement are in all of the sandstones (5) The Bromide has alternating cemented bands next to porous bands whereas the Tonkawa has alternating cement bands next to clay matrix rich bands

Summary

Shallow burial depth

The Fortuna sandstone was not extensively compacted, thus primary porosity was not obliterated. Clay matrix material is not tightly compacted, therefore, partially enclosed quartz grains and occlusion of primary porosity is seen Pseudomatrix and pore-filling clays partially occluded primary porosity Silica precipitation as quartz-overgrowth cement is in minor amounts. The quartz grains were not compacted to the extent needed to achieve pressure solution dissolution

Moderate burial depth

The Tonkawa, Marchand, Culp, and Melton sandstones were subjected to compaction which occluded primary porosity except where it was preserved by clay coatings on detrital grains Pseudomatrix, formed by the ductile deformation of detrital grains, has occluded some primary porosity. Samples were cemented by calcite and silica. Banding is present as silica-cemented bands alternating with compacted clay matrix-rich bands The clay matrix, present in some areas, was tightly compacted between the quartz grains occluding primary porosity and inhibiting silica cementation.

Deep burial depth

The Red Fork, Springer, and Bromide sandstones were subjected to compaction occluding primary porosity except where it was preserved by clay coatings on detrital grains Samples have been cemented by silica, calcite and/or dolomite cement. In clay-rich, clastic rocks, compaction "squeezed" the clay matrix around the quartz grains occluding primary porosity. Silica cement was inhibited by this tightly compacted matrix. The silica-rich clastic rocks show banded features of silica-cemented bands alternating with porous bands This diagenetic banding in deeply buried rocks of the Anadarko Basin has been documented by Tigert and Al-Shaieb (1990) and Al-Shaieb and others (1994).

The sandstones that were moderately to deeply buried had primary porosity occluded, except where it was preserved by clay coatings With the loss of primary porosity by compaction, cementation, and/or clay matrix, the sandstone could form an intra-stratum seal If the seal could withstand an increase in pressure, it would be possible for an intra-stratum compartment to form. The seal and the interior compartment would be located entirely within a sedimentary stratum.

CHAPTER VII

CONCLUSIONS

The examination of shallow, moderately, and deeply buried sandstones within the Anadarko Basin integrated petrographic analyses, petrologic analyses, and x-ray diffraction analyses. The following conclusions were formulated using the findings of this study.

(1) Evidence collected from petrologic logs, thin-section analyses, paleotectonic history, and geologic settings were used to interpret the depositional environments of the sandstones studied. The depositional environments of the sandstones were interpreted to be (a) Fortuna, an alluvial environment, (b) Tonkawa, a shallow marine shelf environment, (c) Marchand, a shallow marine shelf/slope environment, (d) Culp, a shallow marine to delta margin environment, (e) Melton, a shallow marine slope environment, (f) Red Fork, a submarine fan to basinal floor environment, (g) Springer, a shallow marine shelf environment, and (h) Bromide, a marine platform environment.

The sandstones studied were classified using QRF sandstone-classification diagrams. The results of this classification are: (a) Fortuna is quartz wacke, (b) Tonkawa is quartz arenite to subfeldspathic lithic arenite, (c) Marchand is sublitharenite to quartz arenite, (d) Culp is quartz arenite, (e) Melton is quartz arenite, (f) Red Fork is lithic wacke, subfeldspathic lithic wacke, and subfeldspathic lithic arenite, (g) Springer is quartz arenite, and (h) Bromide is quartz arenite.

(3) Pressure-depth profiles of the study area identified the location of normal pressured and overpressured zones with respect to the megacompartment complex. The Fortuna, Tonkawa, Marchand, Culp, and Melton sandstones are normally pressured and above the megacompartment complex. The Red Fork and Springer sandstones are overpressured and within the megacompartment complex The Bromide sandstone is normally pressured and below the megacompartment complex.

(4) Characteristics of shallow buried sandstones in the Anadarko Basin include

(a) Not extensively compacted, thus primary porosity is preserved.

(b) Clay matrix is not tightly compacted, only partially occluded primary porosity.

(c) Compaction ductilely deformed detrital grains which occluded some primary porosity

(d) Pore-filling clays (kaolinite and chlorite) occluded some primary porosity.

(e) Silica precipitation as quartz-overgrowth cement is in minor amounts.

(f) Diagenetic banding is absent.

(g) Calcite cement is absent.

(h) Grains were not touching or, if touching, the contacts were slightly compacted.

(5) Characteristics of moderately buried sandstones in the Anadarko Basin.

(a) Compaction occluded primary porosity, except where it was preserved by clay coatings on detrital grains

(b) Compaction ductilely deformed some detrital grains which occluded some primary porosity.

(c) Sandstones are cemented by calcite and silica cements.

(d) Silica-cemented bands alternate with clay matrix-rich bands.

(e) Clay matrix, present in some areas, was tightly compacted between quartz grains. This occluded primary porosity and inhibited silica precipitation.

(f) Pore-filling clays (kaolinite and chlorite) occluded some primary porosity.

(g) Stylolites, which are pressure solution features, were filled with organic material.

(h) Quartz-grain pressure solution dissolution occurred.

(6) Characteristics of deeply buried sandstones in the Anadarko Basin:

(a) Compaction occluded primary porosity, except where it was preserved by clay coatings on detrital grains.

(b) Sandstones are cemented by calcite, silica, and/or dolomite cements.

(c) In clay-rich clastic rocks, compaction "squeezed" the clay matrix around grains. This occluded primary porosity and inhibited silica precipitation.

(d) In silica-rich clastic rocks, silica-cemented bands alternate with porous bands.

(e) Pore-filling clays (kaolinite and chlorite) occluded some primary porosity.

(f) Quartz-grain pressure solution dissolution occurred.

(g) Stylolites, which are pressure solution features, were filled with organic material.

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APPENDIX A

DEPOSITIONAL ENVIRONMENTS

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
FORTUNA	Anadarko Basin slowly subsiding (1,2) Amarillo-Wichita Uplift (2) and Arbuckle Mountains (1) were positive elements	Circulation of water within the Anadarko Basin became more restricted and shallower (1,2). A marine regression marked the beginning of Guadalupian time and continued through Leonardian time (1).	Noble Olson ss = shallow marine	Prosperity ss = shallow marine restricted environemnt	Monocrystalline quartz Polycrystalline quartz Plagioclase Shale fragment Muscovite Pyrite Hematite Zircon Tourmaline Detrital chlorite Kaolinite Illite Chlorite

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENT JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Clayey matrix	Horizontal laminae Bioturbation Ripple laminae Cross bedding Flowage Concretions Sloped bedding Mottled bedding Caliche Red beds		Alluvial	(1) Berryhill, Jr., (1967) (2) Johnson and others, (1988)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
TONKAWA	Anadarko Basin subsiding (3,4) Arbuckle Mountains, Amarillo-Wichita Uplift, Ouachita Uplift, and Sierra Grande Uplift were positive elements (3,4)	Deepening of the Anadarko Basin was accompanied by the uplifting of the Amarillo-Wichita Uplift and the Arbuckle Mountains (3,4). Fine-grained detritus derived from the Ouachita area to the east and the Sierre Grande Uplift to the northeast was deposited into the basin (3).	Avant Limestone = shallow marine	Lovell ss = shallow marine shelf	Monocrystalline quartz Polycrystalline quartz Plagioclase Granophyre Shale fragments Chert fragments Glauconite Pyrite Zircon Tourmaline Detrital chlorite Kaolinite Chlorite Fossil fragments Organic material

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENT JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Calcite	Horizontal laminae Bioturbation Ripple laminae Flowage Concretions/bands Sloped bedding Burrows Stylolites Woody material		Shallow marine shelf	(3) McKee,Crosby and others (1975) (4) Rascoe and Adler (1983)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
MARCHAND	Anadarko Basin rapidly subsiding (2) Amarillo-Wichita Uplift (2,3), Ouachita Uplift, and Apishapa Uplift were positive elements (2)	During Missourian time the Amarillo-Wichita uplift, Ouachita Uplift, and Apishapa Uplift were positive elements and source areas for a large volume of sediments deposited into the actively subsiding basin (3).	Culp ss = shallow marine to a delta margin	Medrano ss = shallow marine slope environment	Monocrystalline quartz Polycrystalline quartz Orthoclase Plagioclase Shale fragments Chert fragments Metamorphic rock fragments Glauconite Muscovite Pyrite Hematite Zircon Tourmaline Detrital chlorite Illite Organic material Fossil fragments

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENT JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Calcite	Horizontal laminae Cross bedding Flowage Concretions/bands Burrows Stylolites Slump structure Flame structure		Shallow marine shelf/slope	(2) Johnson and others (1988) (3) McKee, Crosby and others (1975)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
CULP	Anadarko Basin rapidly subsiding (2) Amarillo-Wichita Uplift (2,3), Ouachita Uplift, and Apishapa Uplift are positive elements (2)	During Missourian time the Amarillo-Wichita uplift, Ouachita Uplift, and Apishapa Uplift were positive elements and source areas for a large volume of sediments deposited into the actively subsiding basin (3).	Marchand ss = shallow marine shelf/ slope	Melton ss = shallow marine slope environment	Monocrystalline quartz Polycrystalline quartz Orthoclase Plagioclase Chert rock fragments Metamorphic rock fragments Muscovite Pyrite Hematite Zircon Tourmaline Detrital chlorite Kaolinite Chlorite

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENTAL JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Calcite	Horizontal laminae Flowage Concretions/bands Burrows Stylolites Slump structure Mottled Bioturbation Ripple laminae Slope bedding Paleosol (rootlet) Abrupt contacts	Abrupt	Shallow marine to a deltaic margin	(2) Johnson and others (1988) (3) McKee, Crosby and others (1975)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
MELTON	Anadarko Basin rapidly subsiding (2) Amarillo-Wichita Uplift (2,3), Ouachita Uplift, and Apishapa Uplift were positive elements (2)	During Missourian time the Amarillo-Wichita uplift, Ouachita Uplift, and Apishapa Uplift were positive elements and source areas for a large volumes of sediments deposited into the actively subsiding basin (3).	upper Glover ss = deeper marine	Culp ss = shallow marine to a deltaic margin	Monocrystalline quartz Polycrystalline quartz Granophyre Plagioclase Chert rock fragments Metamorphic rock fragments Glauconite Muscovite Pyrite Hematite Collophane Tourmaline Fossil fragments Kaolinite Illite Chlorite Woody material

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENT JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Calcite	Horizontal laminae Cross bedding Flowage Concretions Bioturbation Ripple laminae Sloped bedding Flame structure Microfaults Abrupt contacts	Abrupt	Shallow marine slope	(2) Johnson and others (1988) (3) McKee, Crosby and others (1975)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
RED FORK	Anadarko Basin is slowly subsiding (3) Amarillo-Wichita Uplift, Arbuckle Uplift, Nemaha Uplift, and Ouachita Uplift were positive elements (3,5)	The seas were more restricted during deposition of the Lower Desmoinesian (3). Regional subsidence was gradual and deposition was continuous in the basin (3). The major marine transgression that deposited Lower Desmoinesian sediments was ocillatory rather than continuous (3).	Inola Limestone = deep marine	Pink limestone = deep marine	Monocrystalline quartz Polycrystalline quartz Orthoclase Plagioclase Perthite Shale rip up clast Chert fragment Carbonate rock fragment Metamorphic rock fragment Granophyre Glauconite Muscovite Biotite Hematite Zircon Tourmaline Detrital Chlorite Kaolinite Organic material

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIROMENTAL JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowth Calcite Clayey matrix	Horizontal laminae Bioturbation Burrows Flowage Stylolites Cross bedding Concretions/bands Ripple laminae Abrupt contact Slump structure Microfaulting Convolute bedding Flute casts Turbidites	Abrupt	Submarine fan to basinal floor	(3) McKee,Crosby and others (1975) (5) Moore (1979)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
SPRINGER	Anadarko Basin gradually subsiding (3) Amarillo-Wichita Uplift and Nemaha Uplift were positive elements (3, 4)	At the close of the Mississippian a general uplift resulted in low-lying land areas and restricted seas (3). The low lying land areas to the north and west were sources of fine detrital sediments (3).	Goddard Fm. = shallow marine	Primrose SS = shallow marine shelf	Monocrystallin quartz Polycrystalline quartz Plagioclase Fossil fragments Pyrite Zircon Tourmaline Collophane Hematite Kaolinite Chlorite Organic material

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENT JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Calcite Dolomite	Horizontal laminae Flowage Ripple laminae Cross bedding Stylolite Graded bedding Sloped bedding Bioturbation Soft sediemnt deformation Burrows Mottled at top	Abrupt contact	Shallow marine shelf	(3) McKee, Crosby and others (1975) (4) Rascoe and Adler (1983)

SANDSTONE	PALEOTECTONIC SETTING	GEOLOGIC HISTORY SERIES	GEOLOGIC SETTING UNIT BELOW	GEOLOGIC SETTING UNIT ABOVE	CONSTITUENTS
BROMIDE	Rapid subsidence in the Anadarko Basin trend (3,6) Canadian shield supplying sediments (2,3) Transcontinental Arch was a positive element (3).	During the Ordovician a transgression occurred over the Transcontinental Arch in the continental interior (3). This rise in sea level resulted in a wide-spread and rapid invasion of the platform south of the arch (3).	Tulip Creek Fm. = shallow marine platform	Viola Springs Fm. = shallow to deep marine platform	Monocrystalline quartz Pyrite Hematite Zircon Collophane Illite Chlorite

CEMENTS/ MATRIX	SEDIMENTARY STRUCTURES	CONTACTS	DEPOSITIONAL ENVIRONMENT JUDGED TO BE MOST PROBABLE	REFERENCES
Quartz overgrowths Calcite Dolomite	Horizontal laminae Flowage Stylolites Micrfaulting Bioturbation Burrows Mottled Concretioons Cross bedding Abrupt contact	Abrupt	Shallow marine platform	(2) Johnson and others (1988) (3) McKee, Crosby and others (1975) (6) Sloss (1988)

APPENDIX B

THIN-SECTION CONSTITUENTS AND AMOUNTS

SANDSTONE	FORTUNA					
DEPTH	2035					
CONSTITUENTS	(%)					
DETRITAL						
Quartz						
monocrystalline	38.0					
polycrystalline	T					
Feldspar						
orthoclase	0.0					
plagioclase	T					
granophyre	0.0					
Rock Fragments						
shale	0.0					
chert	0.0					
carbonate	0.0					
metamorphic	0.0					
Other grains						
glauconite	0.0					
fossil fragments	0.0					
muscovite	T					
biotite	T					
zircon	0.2					
tourmaline	1.0					
collophane	0.0					
detrital chlorite	0.0					
hematite	T					
pyrite	1.8					
MATRIX						
clayey	27.8					
DIAGENETIC						
Cements						
quartz	P					
calcite	0.0					
dolomite	0.0					
siderite	0.0					
Clays						
kaolinite	T					
illite	T					
chlorite	2.0					
Other						
organic material	0.0					
POROSITY						
primary	39.2					
secondary	2.0					
QRF NORMALIZED						
clay matrix (%)	42.2					
quartz (%)	57.8					
feldspar (%)	0.0					
rock Fragment (%)	0.0				T = trace amount	
Total	100.0					

SANDSTONE	TONKAWA					
DEPTH	8953	8955	8957			
CONSTITUENTS	(%)	(%)	(%)			
DETRITAL						
Quartz						
monocrystalline	69.0	54.6	72.4			
polycrystalline	T	4.0	2.0			
Feldspar						
orthoclase	T	0.0	0.0			
plagioclase	T	0.0	T			
perthite	0.0	0.0	0.0			
granophyre	0.0	T	T			
Rock Fragments						
shale	18.0	0.4	17.2			
chert	T	0.6	0.8			
carbonate	0.0	0.0	0.0			
metamorphic	0.0	0.0	0.0			
Other grains						
glauconite	0.0	T	0.6			
fossil fragments	T	0.6	0.0			
muscovite	0.0	0.0	0.0			
biotite	0.0	0.0	0.0			
zircon	T	T	T			
tourmaline	0.0	T	T			
collophane	0.0	0.0	0.0			
detrital chlorite	T	T	0.0			
hematite	0.0	0.4	0.0			
pyrite	T	0.0	0.0			
MATRIX						
clayey	8.0	0.0	7.0			
DIAGENETIC						
Cements						
quartz	17.5	10.8	14.3			
calcite	10.2	35.2	5.0			
dolomite	0.0	T	T			
siderite	0.0	0.0	0.0			
Clays						
kaolinite	1.2	0.0	2.0			
illite	T	0.0	T			
chlorite	1.6	3.4	T			
Other						
organic material	T	0.0	0.0			
POROSITY						
primary	0.0	0.0	0.0			
secondary	T	0.8	T			
QRF NORMALIZED						
quartz (%)	79.0	98.3	80.5			
feldspar (%)	T	0.0	0.0			
rock Fragment (%)	21.0	1.7	19.5		T= trace amount	
Total	100.0	100.0	100.0			

SANDSTONE	MARCHAND					
DEPTH	9860	9912	9924			
CONSTITUENTS	(%)	(%)	(%)			
DETRITAL						
Quartz						
monocrystalline	74.8	68.4	74.4			
polycrystalline	1.0	1.0	2.6			
Feldspar						
orthoclase	T	T	T			
plagioclase	0.2	1.8	T			
granophyre	0.0	0.0	0.0			
Rock Fragments						
shale	0.0	T	0.0			
chert	0.0	1.2	0.4			
carbonate	0.0	0.0	0.0			
metamorphic	9.0	1.0	0.6			
Other grains						
glauconite	1.4	T	0.0			
fossil fragments	0.0	2.0	0.0			
muscovite	1.0	0.8	0.0			
biotite	0.0	0.0	0.0			
zircon	T	0.2	0.0			
tourmaline	T	T	0.0			
collophane	0.0	0.0	0.0			
detrital chlorite	0.0	0.0	0.0			
hematite	0.4	2.6	T			
pyrite	4.6	0.8	T			
MATRIX						
clayey	0.0	9.0	0.0			
DIAGENETIC						
Cements						
quartz	10.3	13.3	9.8			
calcite	4.2	19.2	4.4			
dolomite	0.0	0.0	0.0			
hematite	0.0	0.0	3.6			
Clays						
kaolinite	T	T	T			
illite	T	T	T			
chlorite	0.6	1.0	T			
Other						
organic material	1.8	T	2.4			
POROSITY						
primary	0.2	0.0	11.6			
secondary	0.8	T	T			
QRF NORMALIZED						
quartz (%)	89.2	94.6	98.7			
feldspar (%)	0.2	2.4	0.0			
rock Fragment (%)	10.6	3.0	1.3		T = trace amount	
Total	100.0	100.0	100.0			

SANDSTONE	CULP						
DEPTH	10395	10403					
CONSTITUENTS	(%)	(%)					
DETRITAL							
Quartz							
monocrystalline	82.6	74.2					
polycrystalline	1.0	1.8					
Feldspar							
orthoclase	T	T					
plagioclase	1.0	T					
granophyre	T	0.0					
Rock Fragments							
shale	0.0	0.0					
chert	0.0	T					
carbonate	0.0	0.0					
metamorphic	T	0.0					
Other grains							
glauconite	0.0	0.0					
fossil fragments	0.0	0.0					
muscovite	0.8	T					
biotite	0.0	0.0					
zircon	T	T					
tourmaline	T	T					
collophane	0.0	0.0					
detrital chlorite	0.0	T					
hematite	0.0	T					
pyrite	0.8	1.4					
MATRIX							
clayey	0.0	0.0					
DIAGENETIC							
Cements							
quartz	9.8	12.3					
calcite	1.6	11.3					
dolomite	0.0	0.0					
siderite	2.8	2.5					
Clays							
kaolinite	0.6	1.2					
illite	T	T					
chlorite	5.0	3.6					
Other							
organic material	0.0	0.0					
POROSITY							
primary	0.0	0.0					
secondary	3.8	4.0					
QRF NORMALIZED							
quartz (%)	98.8	100.0					
feldspar (%)	1.2	0.0					
rock Fragment (%)	0.0	0.0			T = trace amount		
Total	100.0	100.0					

SANDSTONE	MELTON					
DEPTH	10878					
CONSTITUENTS	(%)					
DETRITAL						
Quartz						
monocrystalline	72.4					
polycrystalline	3.2					
Feldspar						
orthoclase	0.0					
plagioclase	0.6					
granophyre	T					
Rock Fragments						
shale	0.0					
chert	0.8					
carbonate	0.0					
metamorphic	T					
Other grains						
glauconite	1.0					
fossil fragments	T					
muscovite	1.2					
biotite	0.0					
zircon	0.0					
tourmaline	T					
collophane	T					
detrital chlorite	0.0					
hematite	T					
pyrite	1.6					
MATRIX						
clayey	0.0					
DIAGENETIC						
Cements						
quartz	7.3					
calcite	5.8					
dolomite	0.0					
siderite	0.0					
Clays						
kaolinite	0.0					
illite	3.4					
chlorite	9.4					
Other						
organic material	0.0					
POROSITY						
primary	0.0					
secondary	3.4					
QRF NORMALIZED						
quartz (%)	98.2					
feldspar (%)	0.8					
rock Fragment (%)	1.0					
Total	100.0				T = trace amount	

SANDSTONE	RED FORK					
DEPTH	14098	14101	14103	14119	14135	14144
CONSTITUENTS	(%)	(%)	(%)	(%)	(%)	(%)
DETRITAL						
Quartz						
monocrystalline	33.6	36.0	54.0	40.0	44.0	15.4
polycrystalline	0.0	0.0	3.4	0.0	2.0	T
Feldspar						
orthoclase	T	0.0	T	0.0	0.0	T
plagioclase	T	T	4.2	T	2.0	2.0
granophyre	0.0	0.0	0.0	0.0	0.0	0.0
Rock Fragments						
shale	0.0	0.0	0.0	0.0	0.0	38.0
chert	0.0	0.0	2.6	0.0	T	6.4
carbonate	4.6	5.6	1.4	18.0	6.2	12.0
metamorphic	30.4	30.2	25.0	22.4	26.0	0.0
Other grains						
glauconite	0.0	0.0	0.0	0.0	T	0.0
fossil fragments	0.0	0.0	0.0	0.0	0.0	0.0
muscovite	3.0	1.2	0.6	3.2	3.8	3.2
biotite	T	0.4	T		T	T
zircon	1.4	1.2	T	0.6	T	T
tourmaline	0.2	T	T	T	T	T
collophane	0.0	0.0	0.0	0.0	0.0	0.0
detrital chlorite	3.8	3.0	1.2	3.0	3.0	0.6
hematite	T	T	T	0.0	0.0	T
pyrite	0.8	1.8	T	T	1.0	0.0
MATRIX						
clayey	17.8	13.0	7.2	12.0	3.0	18.4
DIAGENETIC						
Cements						
quartz	3.8	3.5	7.8	2.3	3.0	1.8
calcite	0.0	0.4	T	0.0	1.0	0.0
dolomite	0.0	0.0	0.0	0.0	0.0	0.0
siderite	0.0	0.0	0.0	0.0	0.0	0.0
Clays						
kaolinite	T	0.4	T	T	T	T
illite	T	T	T	T	T	T
chlorite	T	T	T	T	T	T
Other						
organic material	3.4	6.2	0.4	0.8	8.0	4.0
POROSITY						
primary	0.0	0.0	0.0	0.0	0.0	0.0
secondary	1.0	0.6	T	T	T	T
QRF NORMALIZED						
quartz (%)	49.0	50.0	63.0	50.0	57.0	21.0
feldspar (%)	0.0	0.0	5.0	0.0	3.0	3.0
rock Fragment (%)	51.0	50.0	32.0	50.0	40.0	76.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

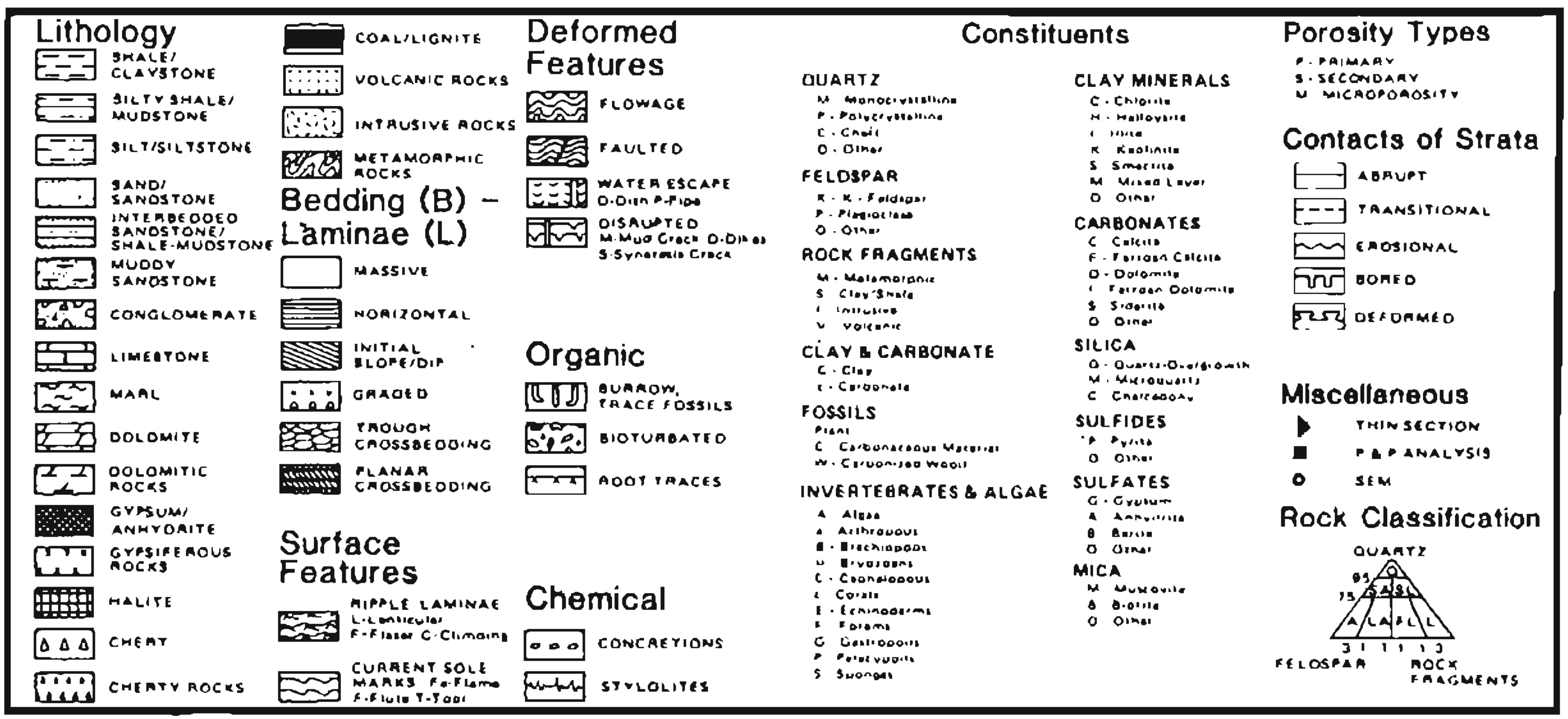
FORMATION	RED FORK					
DEPTH	14147					
CONSTITUENTS	(%)					
DETRITAL						
Quartz						
monocrystalline	37.0					
polycrystalline	T					
Feldspar						
orthoclase	T					
plagioclase	5.0					
granophyre	0.0					
Rock Fragments						
shale	0.0					
chert	T					
carbonate	14.0					
metamorphic	18.0					
Other grains						
glauconite	T					
fossil fragments	0.0					
muscovite	1.6					
biotite	T					
zircon	0.4					
tourmaline	T					
collophane	0.0					
detrital chlorite	T					
hematite	0.0					
pyrite	0.0					
MATRIX						
clayey	13.4					
DIAGENETIC						
Cements						
quartz	5.0					
calcite	9.0					
dolomite	0.0					
siderite	0.0					
Clays						
kaolinite	0.6					
illite	T					
chlorite	T					
Other						
organic material	1.0					
POROSITY						
primary	0.0					
secondary	T					
QRF NORMALIZED						
quartz (%)	50.0					
feldspar (%)	7.0					
rock Fragment (%)	43.0					
Total	100.0				T = trace amount	

SANDSTONE	SPRINGER					
DEPTH	10901	10906	10912			
CONSTITUENTS	(%)	(%)	(%)			
DETRITAL						
Quartz						
monocrystalline	56.2	72.6	59.4			
polycrystalline	0.6	T	T			
Feldspar						
orthoclase	0.0	0.0	0.0			
plagioclase	T	0.0	0.0			
granophyre	0.0	0.0	0.0			
Rock Fragments						
shale	0.0	0.0	0.0			
chert	0.0	0.0	0.0			
carbonate	0.0	0.0	T			
metamorphic	0.0	0.0	0.0			
Other grains						
glauconite	0.0	0.0	0.0			
fossil fragments	T	T	2.4			
muscovite	0.0	0.0	0.0			
biotite	0.0	0.0	0.0			
zircon	T	T	T			
tourmaline	T	T	T			
collophane	T	0.0	T			
detrital chlorite	0.0	0.0	0.0			
hematite	0.0	0.6	T			
pyrite	T	3.2	T			
MATRIX						
clayey	0.0	0.0	0.0			
DIAGENETIC						
Cements						
quartz	9.2	7.3	11.8			
calcite	39.2	T	17.6			
dolomite	0.0	0.0	0.0			
siderite	0.0	0.0	0.0			
Clays						
kaolinite	T	2.6	T			
illite	T	T	T			
chlorite	0.0	4.8	1.0			
Other						
organic material	T	T	T			
POROSITY						
primary	4.0	14.2	16.6			
secondary	2.0	2.0	3.0			
QRF NORMALIZED						
quartz (%)	100.0	100.0	100.0			
feldspar (%)	0.0	0.0	0.0			
rock Fragment (%)	0.0	0.0	0.0		T = trace amount	
Total	100.0	100.0	100.0			

SANDSTONE	BROMIDE					
DEPTH	13375	13389	13408			
CONSTITUENTS	(%)	(%)	(%)			
DETRITAL						
Quartz						
monocrystalline	75.8	54.4	94.6			
polycrystalline	0.0	0.0	0.0			
Feldspar						
orthoclase	0.0	0.0	0.0			
plagioclase	0.0	0.0	0.0			
Rock Fragments						
shale	0.0	0.0	0.0			
chert	0.0	0.0	0.0			
carbonate	0.0	0.0	0.0			
metamorphic	0.0	0.0	0.0			
granophyre	0.0	0.0	0.0			
Other grains						
glauconite	0.0	0.0	0.0			
fossil fragments	0.0	0.0	0.0			
muscovite	0.0	0.0	0.0			
biotite	0.0	0.0	0.0			
zircon	0.0	T	T			
tourmaline	0.0	0.0	0.0			
collophane	T	0.0	0.0			
detrital chlorite	0.0	0.0	0.0			
hematite	T	0.0	0.0			
pyrite	T	T	0.0			
MATRIX						
clayey	0.0	0.0	0.0			
DIAGENETIC						
Cements						
quartz	13.8	14.8	9.8			
calcite	11.8	2.4	0.0			
dolomite	5.4	43.2	0.0			
siderite	0.0	0.0	0.0			
Clays						
kaolinite	0.0	0.0	0.0			
illite	0.0	0.0	T			
chlorite	0.0	0.0	1.2			
Other						
organic material						
POROSITY						
primary	0.0	0.0	4.2			
secondary	7.0	T	T			
QRF NORMALIZED						
quartz (%)	100.0	100.0	100.0			
feldspar (%)	0.0	0.0	0.0			
rock Fragment (%)	0.0	0.0	0.0		T = trace amount	
Total	100.0	100.0	100.0			

APPENDIX C

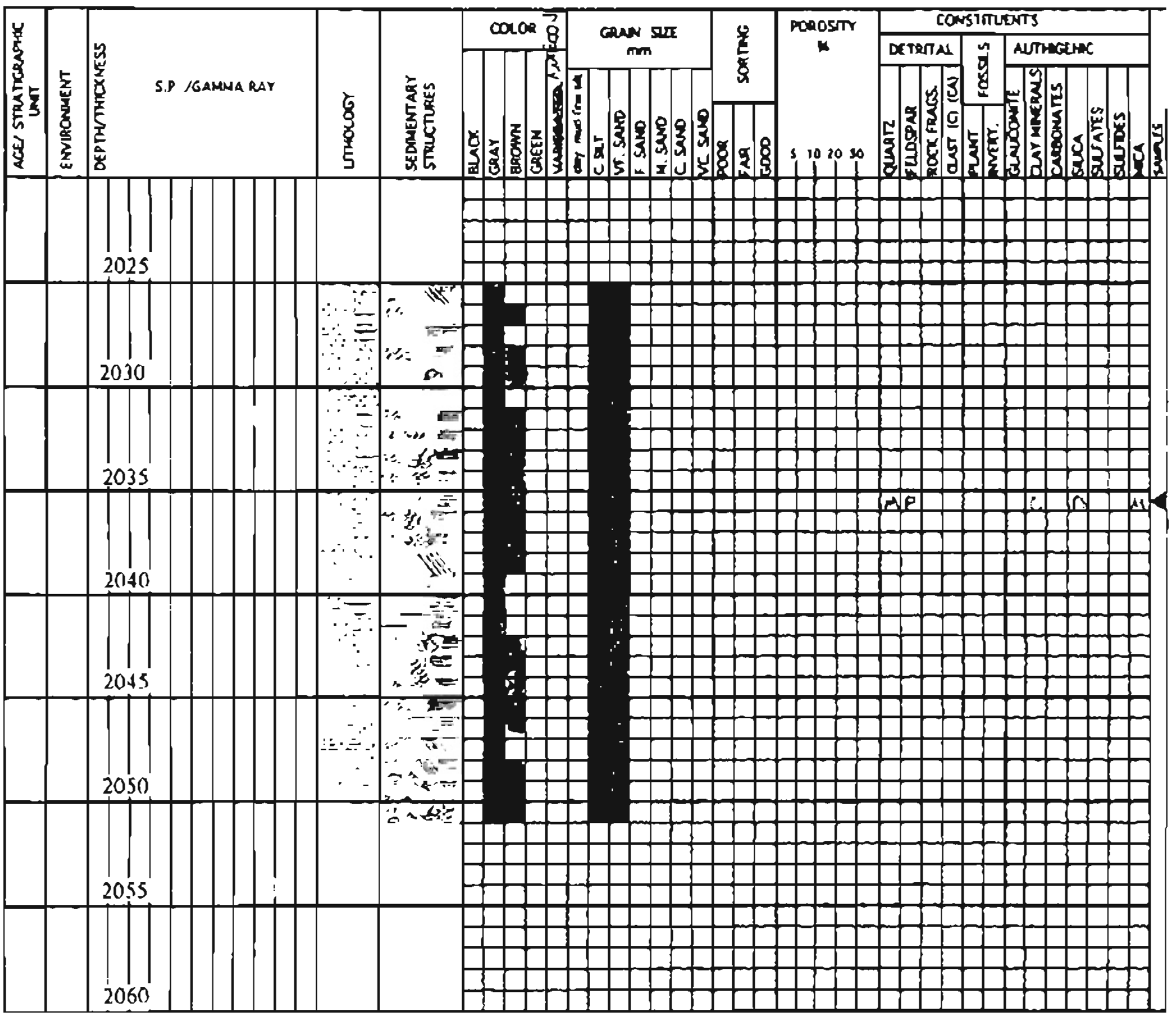
PETROLOGS

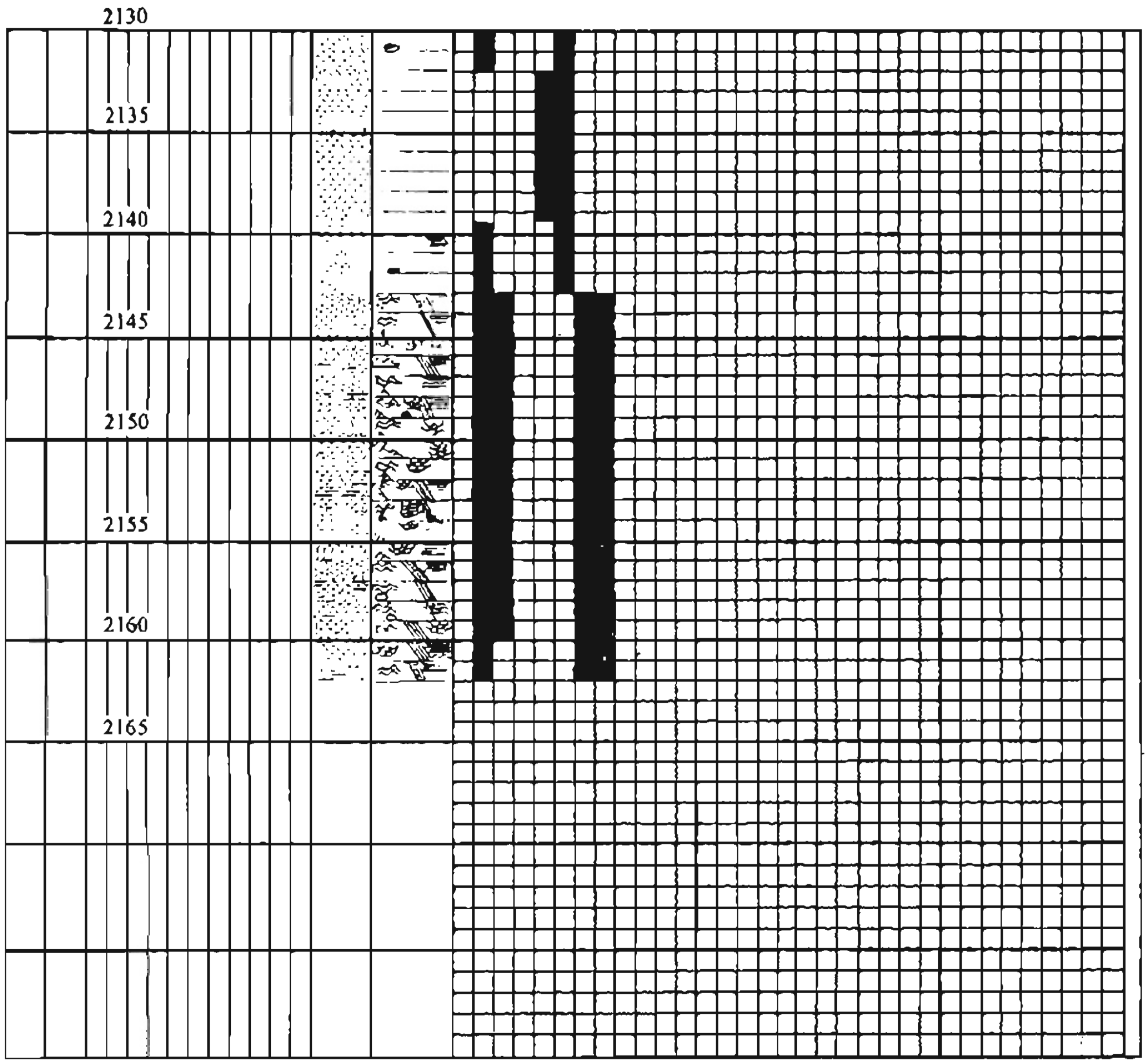

Lithology
SHALE/ CLAYSTONE
SILTY SHALE/ MUDSTONE
SILT/SILTSTONE
SAND/ SANDSTONE
INTERBEDDED SANDSTONE/ SHALE-MUDSTONE
MUDDY SANDSTONE
CONGLOMERATE
LIMESTONE
MARL
DOLOMITE
DOLOMITIC ROCKS
GYPSUM/ ANHYDRITE
GYPSIFEROUS ROCKS
HALITE
CHERT
CHERTY ROCKS
COAL/LIGNITE
VOLCANIC ROCKS
INTRUSIVE ROCKS
METAMORPHIC ROCKS
Bedding (B) – Laminae (L)
MASSIVE
HORIZONTAL
INITIAL SLOPE/DIP
GRADED
TROUGH CROSSBEDDING
PLANAR CROSSBEDDING
Surface Features
RIPPLE LAMINAE
CURRENT SOLE MARKS
Deformed Features
FLOWAGE
FAULTED
WATER ESCAPE
DISRUPTED
Organic
BURROW, TRACE FOSSILS
BIOTURBATED
ROOT TRACES
Chemical
CONCRETIONS
STYLOLITES
Constituents
QUARTZ
FELDSPAR
ROCK FRAGMENTS
CLAY & CARBONATE
FOSSILS
INVERTEBRATES & ALGAE
CLAY MINERALS
CARBONATES
SILICA
SULFIDES
SULFATES
MICA
Porosity Types
P - PRIMARY
S - SECONDARY
M - MICROPOROSITY
Contacts of Strata
ABRUPT
TRANSITIONAL
EROSIONAL
BORED
DEFORMED
Miscellaneous
THIN SECTION
P & P ANALYSIS
SEM
Rock Classification
QUARTZ
FELDSPAR
ROCK FRAGMENTS

COMPANY MIDCON CENTRAL EXPLORATION COMPANY

WELL NAME/ LOCATION ELIZABETH NO. 10 / 6N-10W-27 CADDO COUNTY, OK.

DEPTH. 2025-2051 2130-2162 INTERVAL: FORTUNA

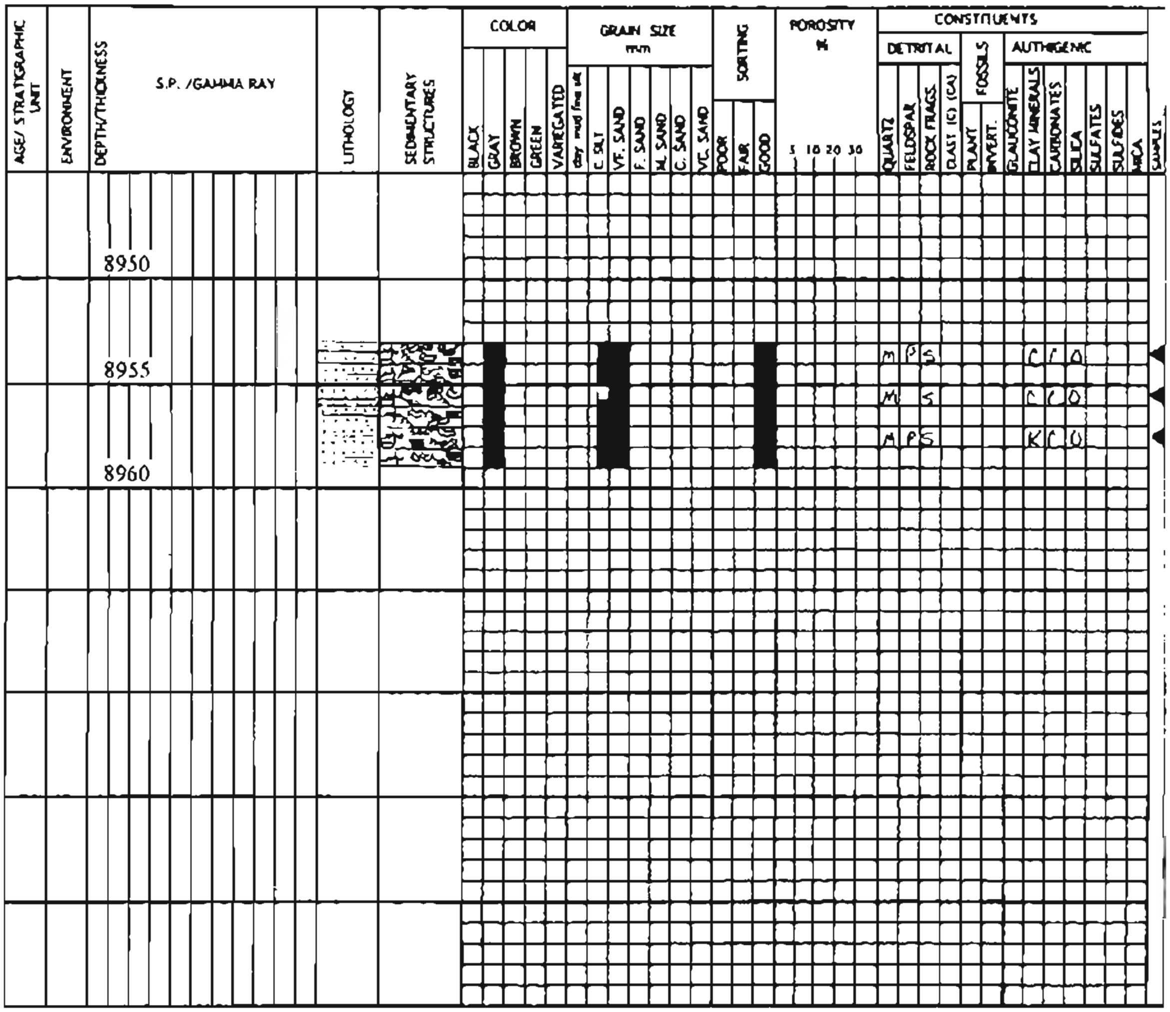



2130
2135
2140
2145
2150
2155
2160
2165

COMPANY LEAR PETROLEUM

WELL NAME/ LOCATION McGLONE NO. 1-35 / 11N-13W-35 CADDO COUNTY, OK.

DEPTH: 8953-8959 INTERVAL: TONKAWA

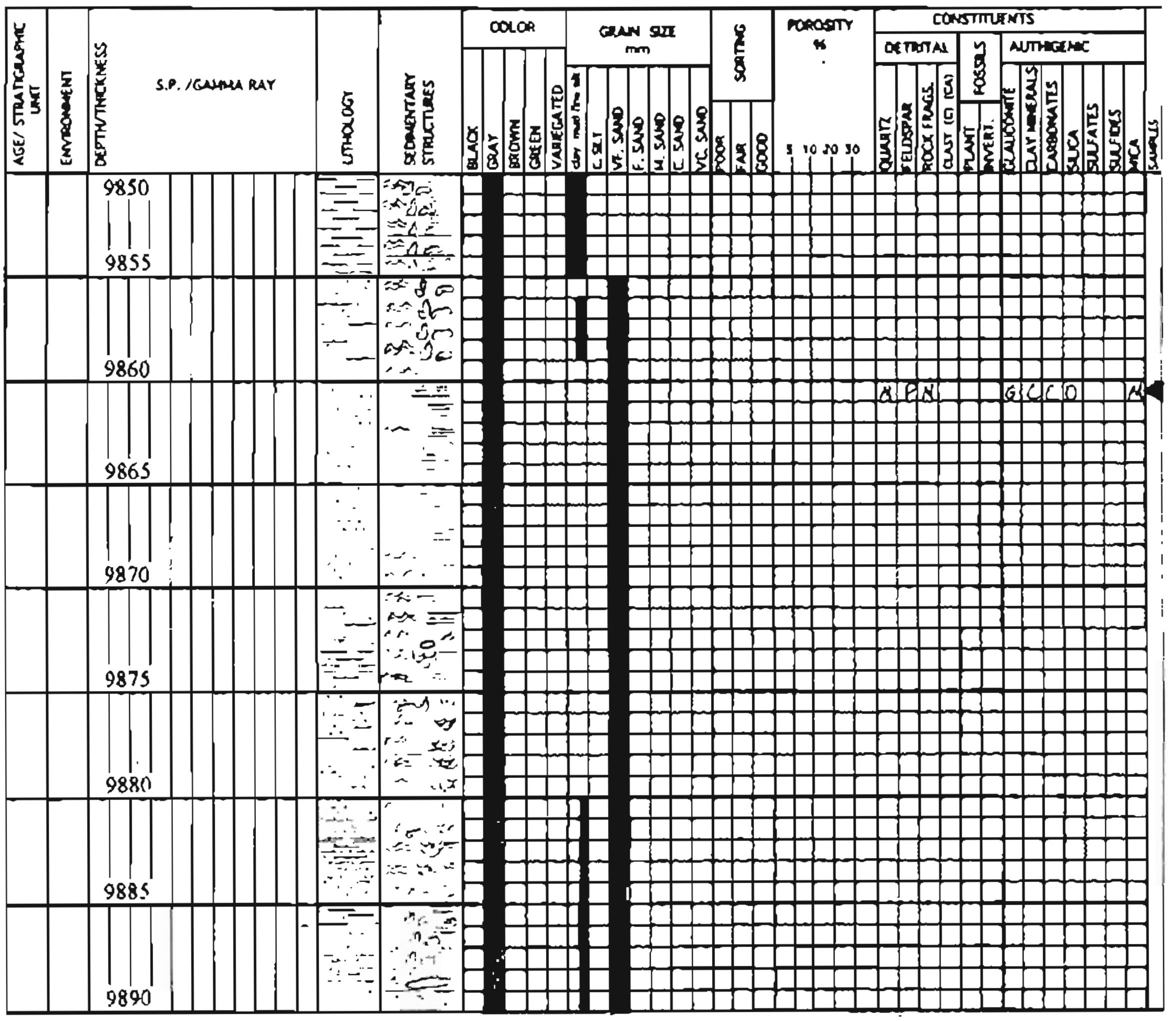


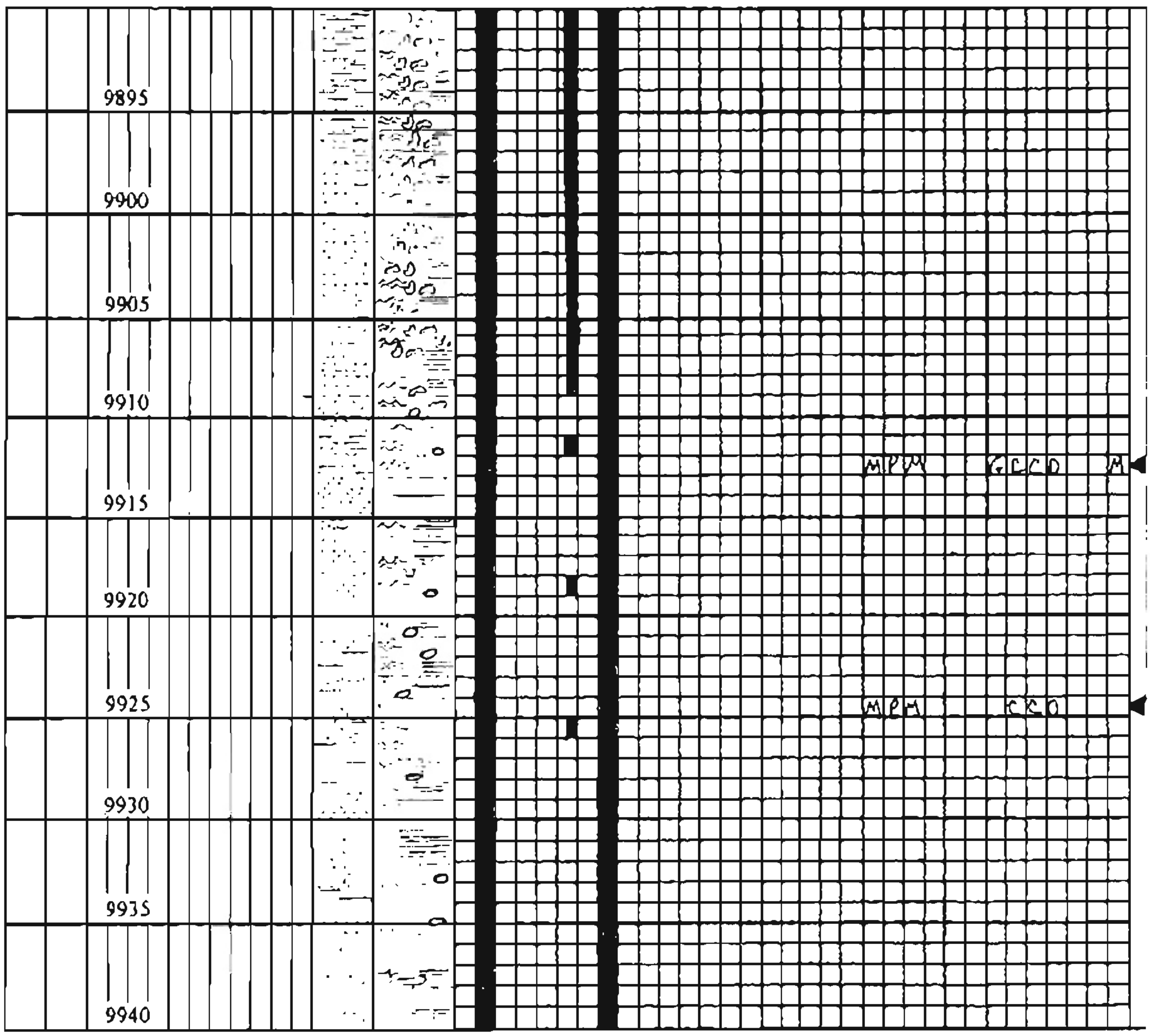
COMPANY APEXCO CORPORATION

WELL NAME/ LOCATION WALKER NO. 1 / 11N-12W-08 CADDO COUNTY, OK.

DEPTH: 9855-9892 INTERVAL: MARCHAND

9911-9958

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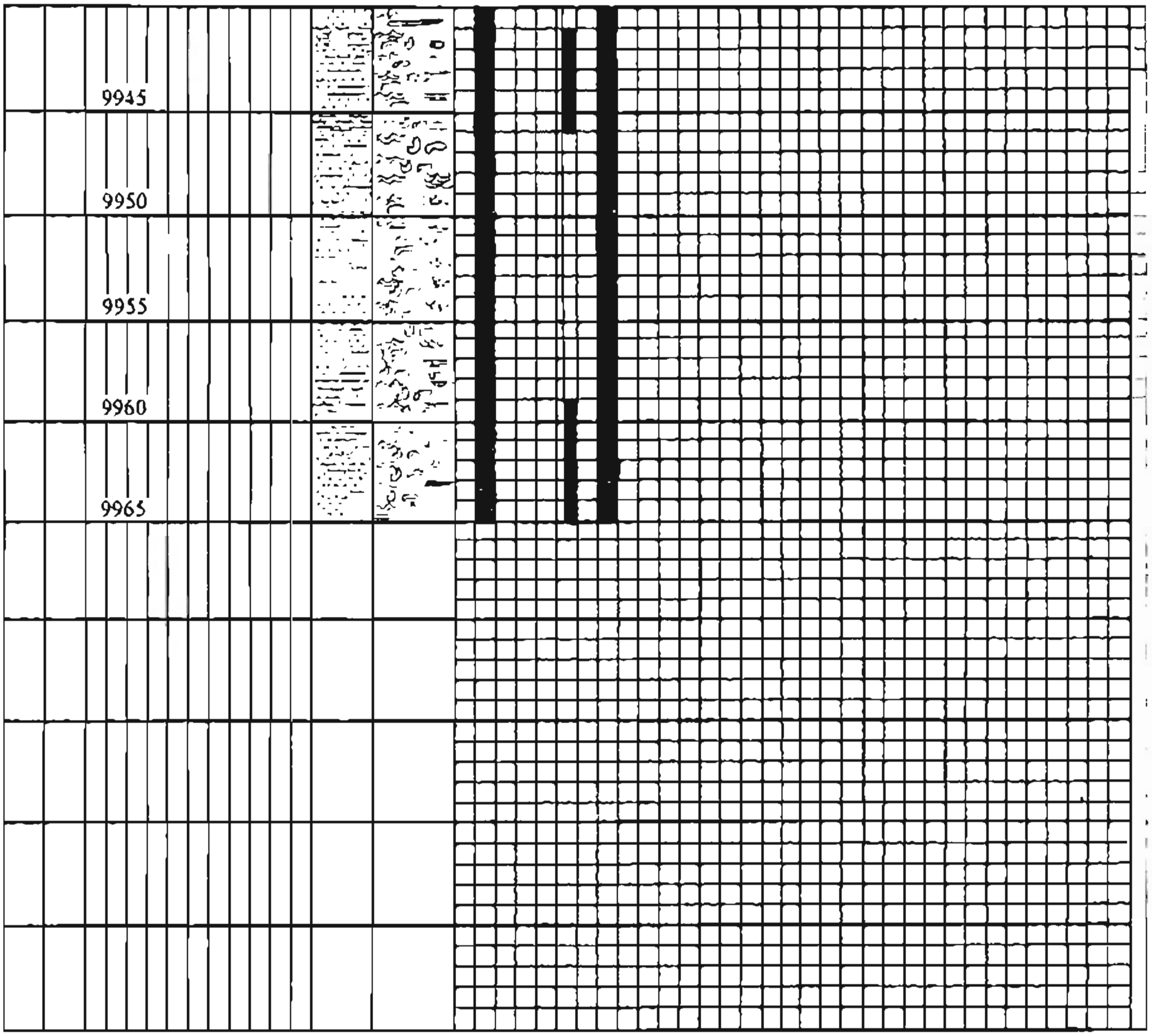
9930
9935
9940
MPM
GCCD
M
MPM
CCO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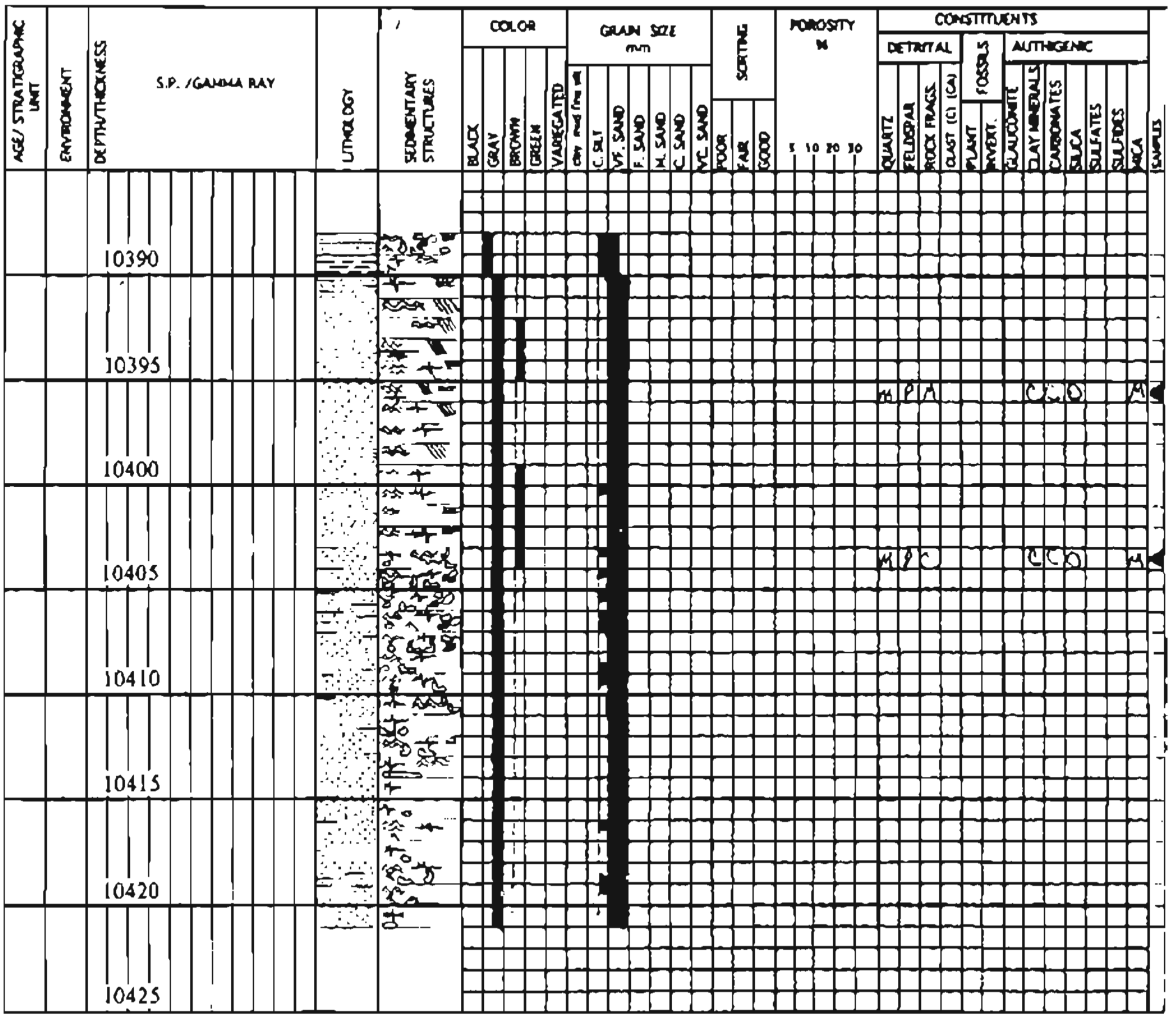
9950
9955
9960
9965

COMPANY LEAR PETROLEUM

WELL NAME/ LOCATION JONES NO. 1-26 / 11N-13W-26 CADDO COUNTY, OK.

DEPTH: 10388-10421 INTERVAL: CULP

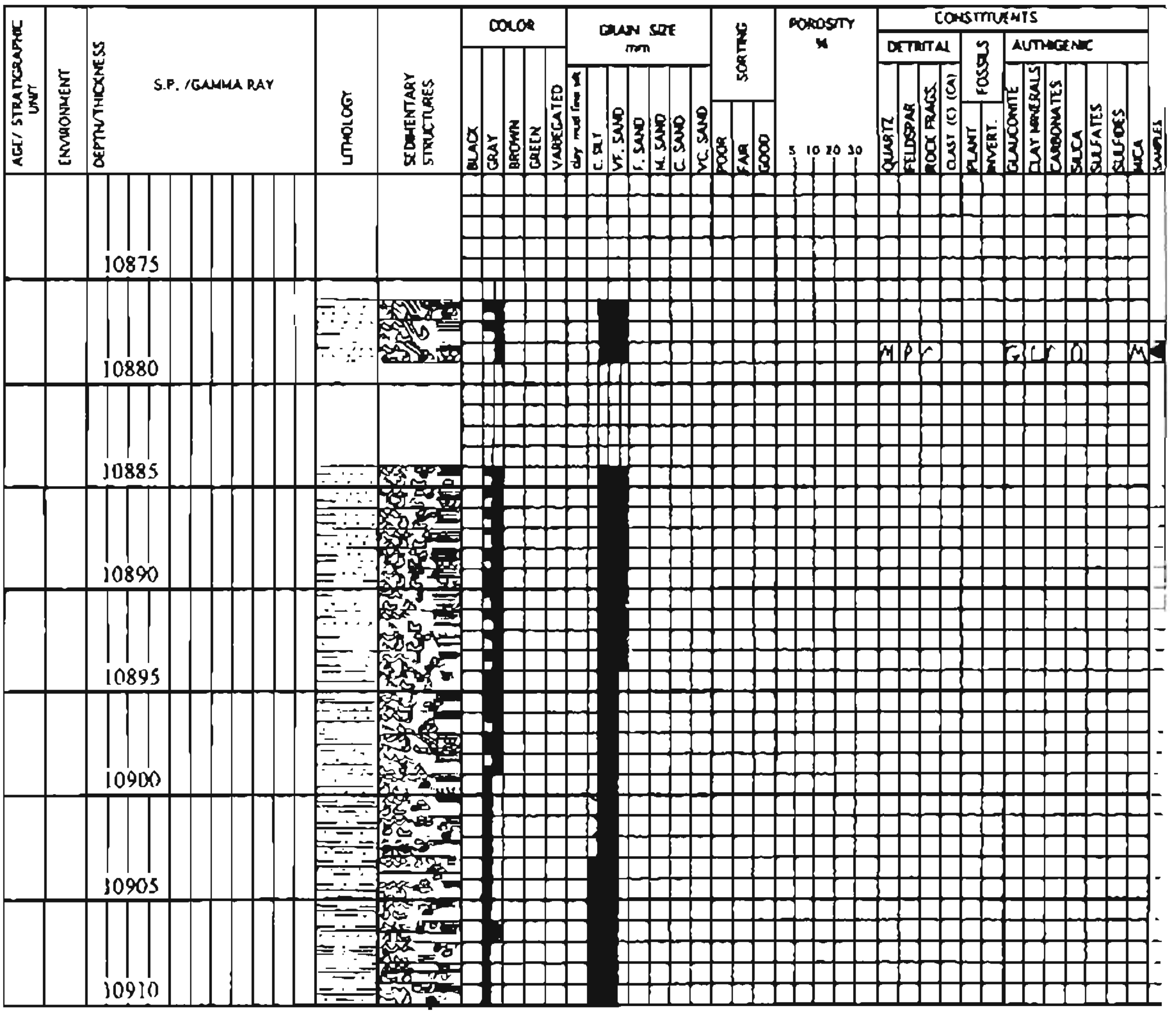


COMPANY LEAR PETROLEUM

WELL NAME/ LOCATION McGLONE NO. 1-35 / 11N-13W-35 CADDO COUNTY, OK.

DEPTH: 10876-10879 INTERVAL: MELTON

10884-10914

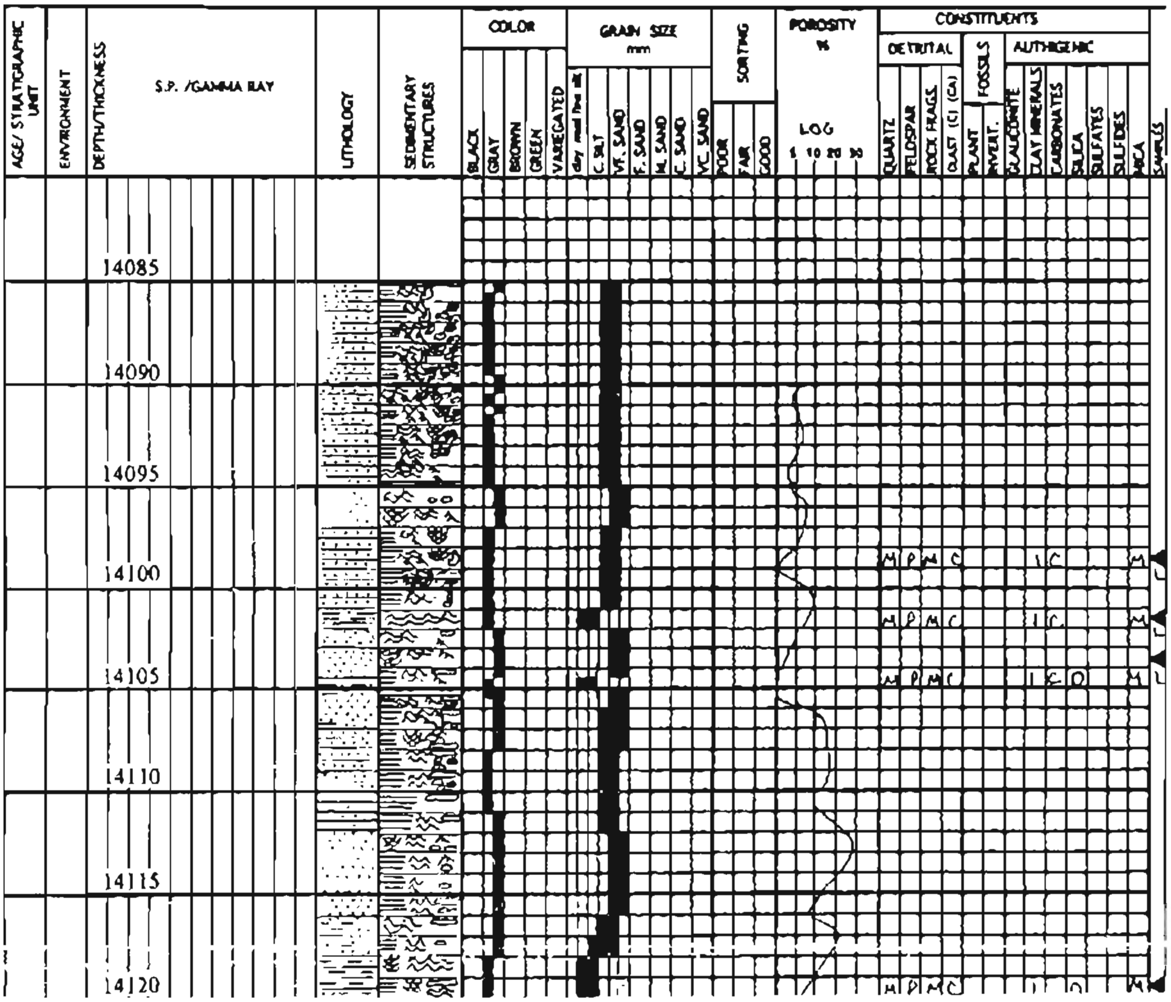


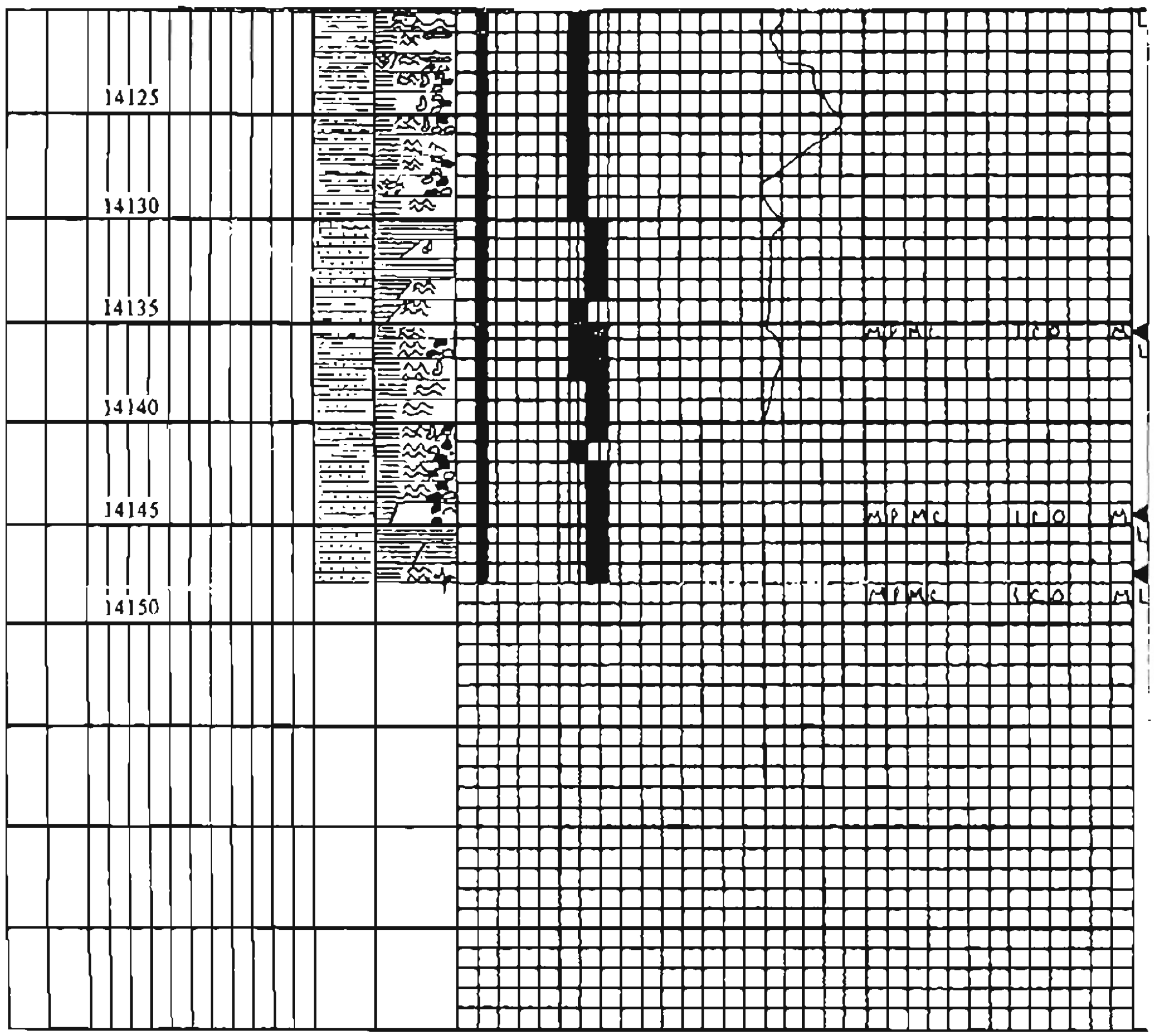
10915

COMPANY HUNT ENERGY CORPORATION

WELL NAME/ LOCATION GILLINGHAM NO. 1 / 9N-12W-12, CADDO COUNTY, OK.

DEPTH: 14085-14147 INTERVAL: RED FORK

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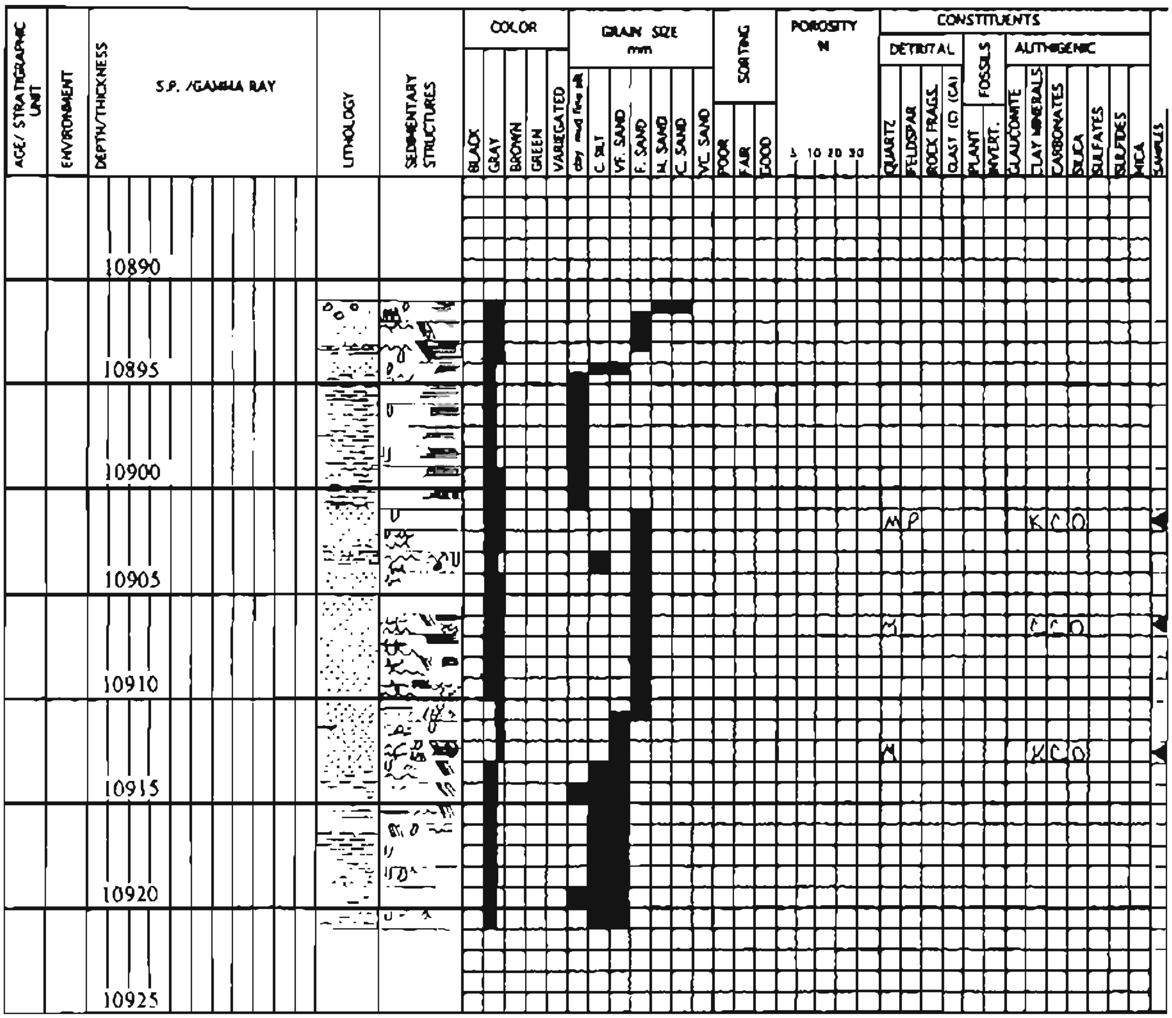
14130
14135
14140
14145
14150

COMPANY MUSTANG PRODUCTION COMPANY

WELL NAME/ LOCATION CRAWFORD NO. 31 / 15N-12W-31 BLAINE COUNTY, OK.

DEPTH: 10891-10921 INTERVAL: SPRINGER

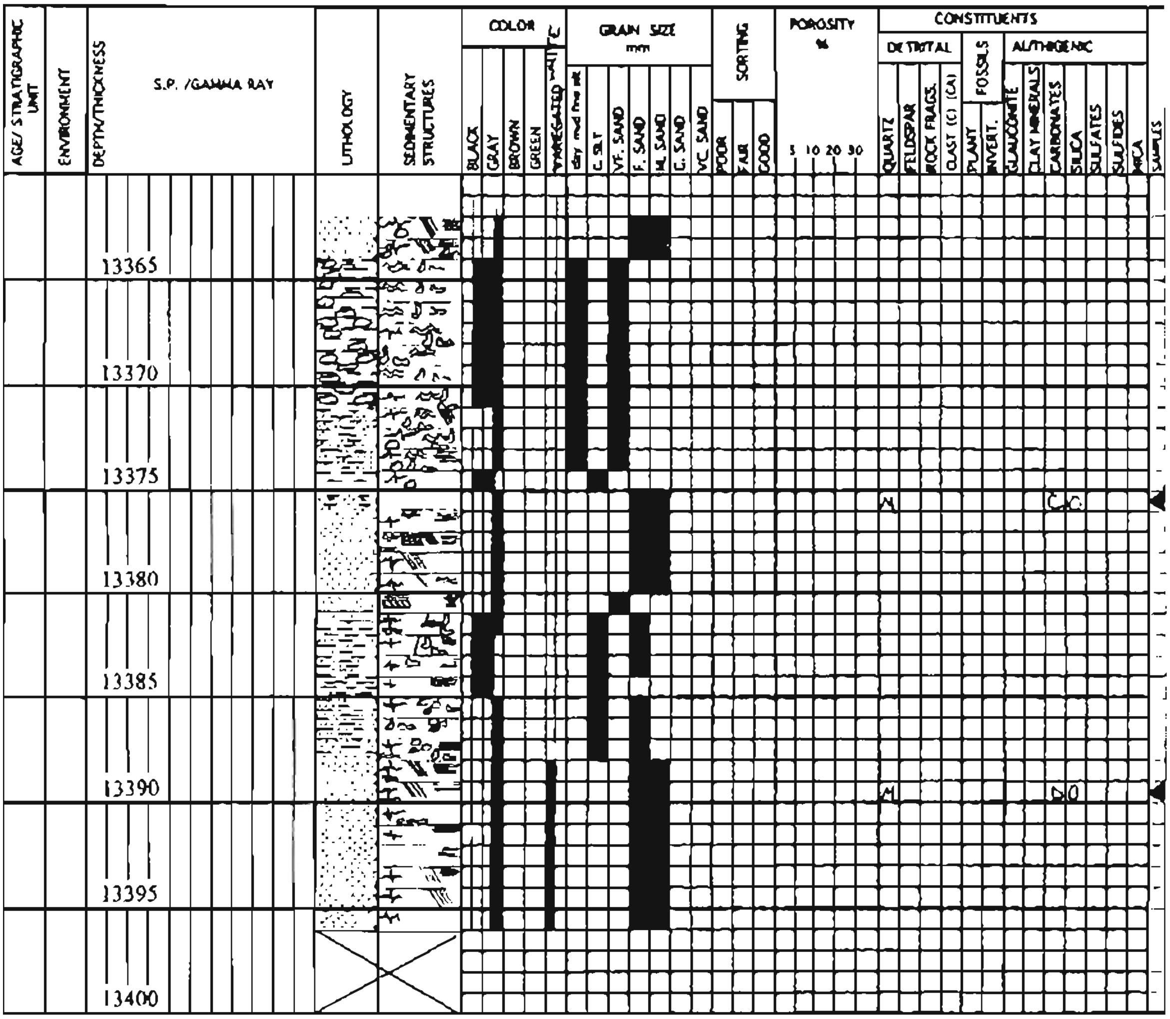


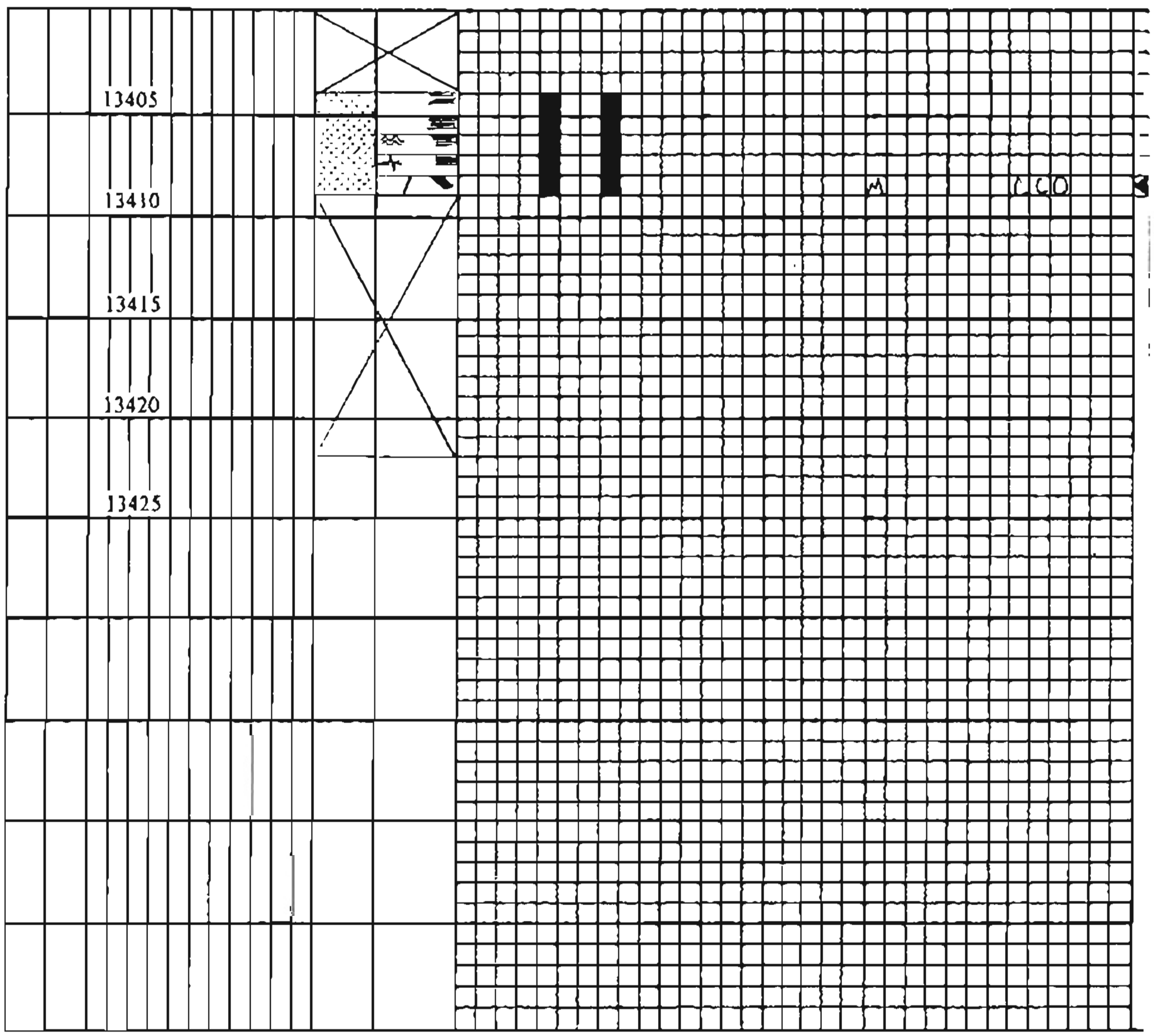
COMPANY MUSTANG PRODUCTION COMPANY

WELL NAME/ LOCATION BARNES NO. 1-25 / 9N-7W-25 GRADY COUNTY, OK.

DEPTH: 13362-13396
13404-13408

INTERVAL: BROMIDE

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APPENDIX D

X-RAY DIFFRACTOMETRY DATA

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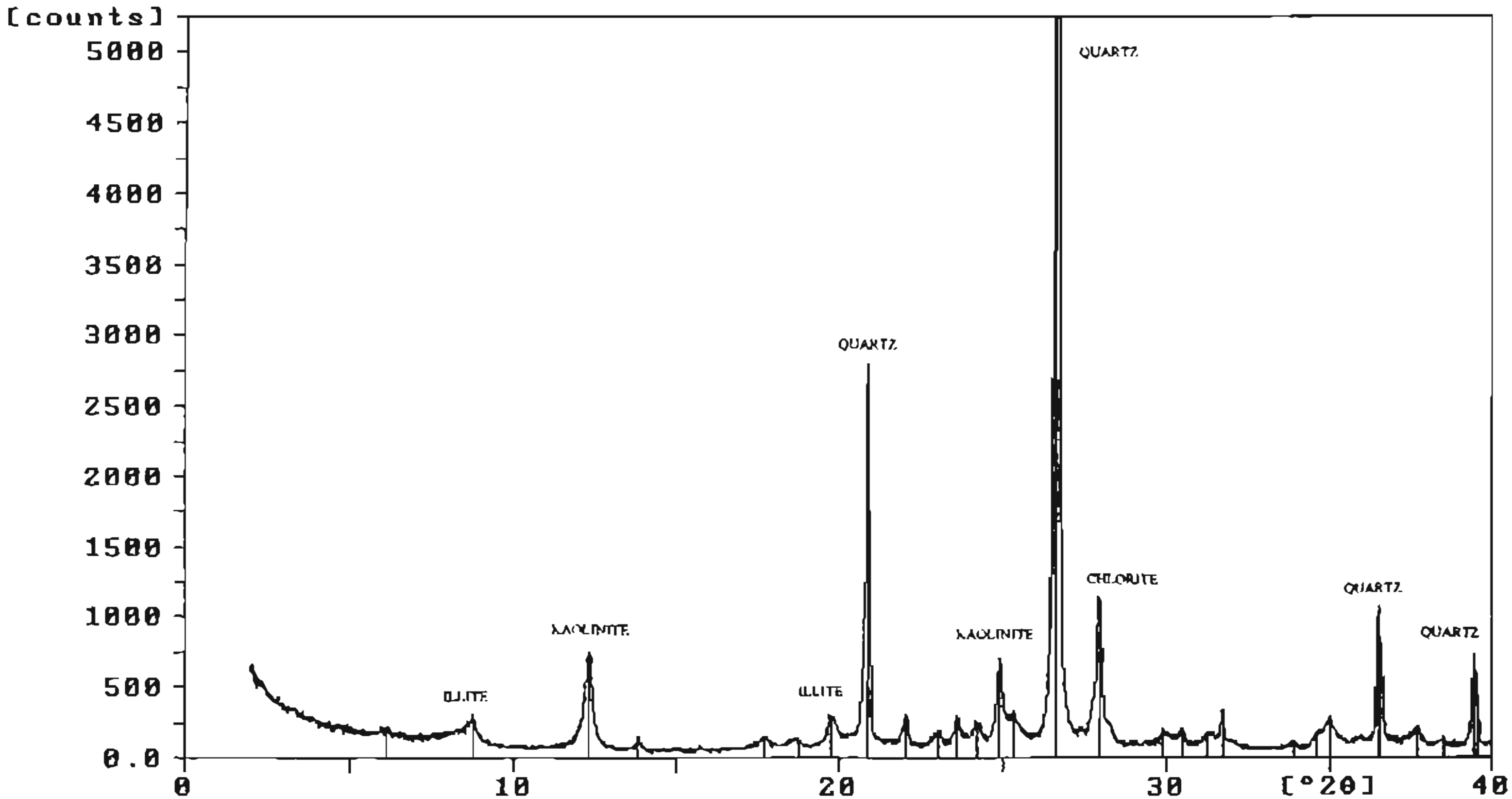

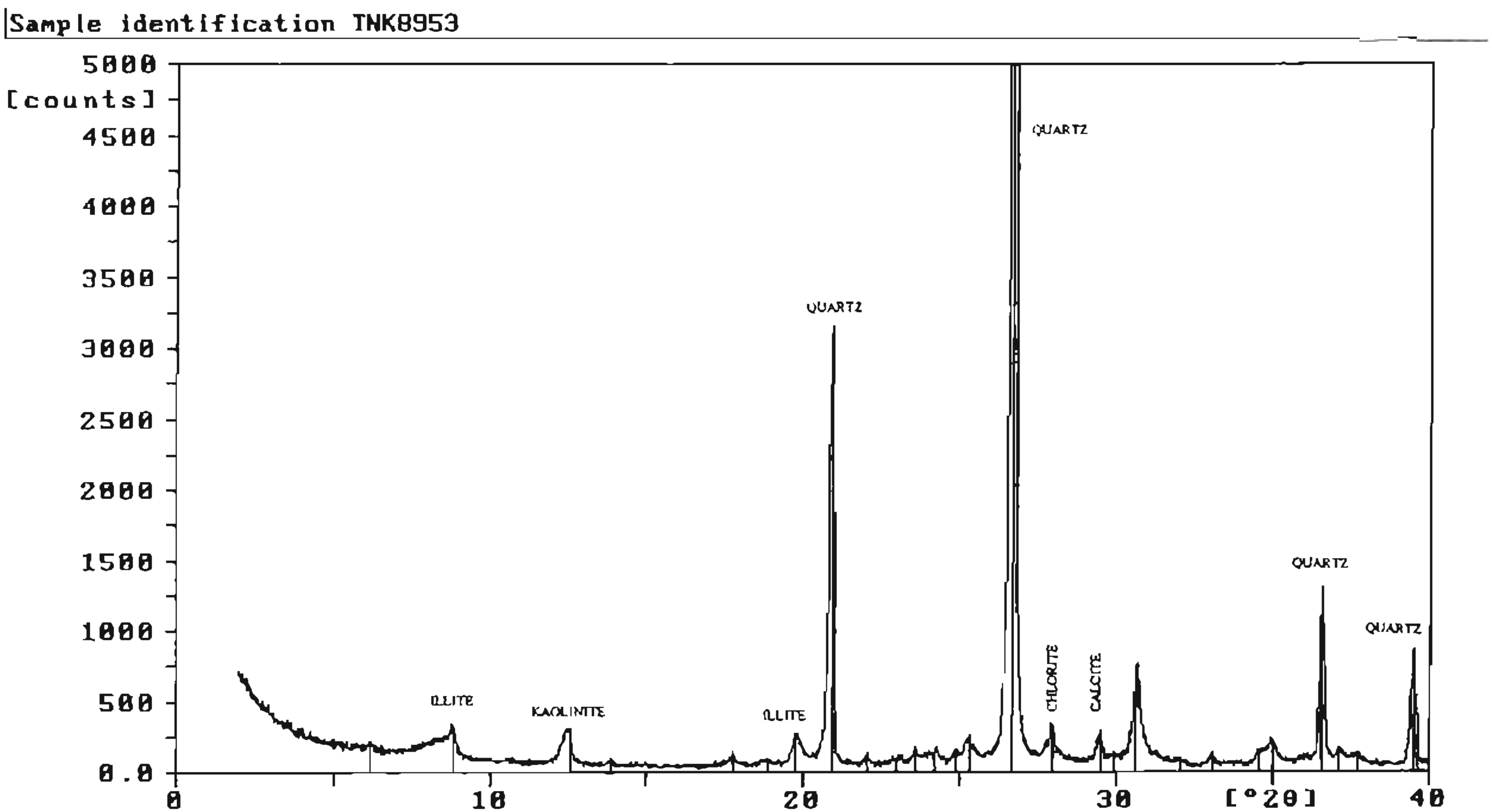
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KAOLINITE
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QUARTZ
QUARTZ
CHLORITE
CALCITE
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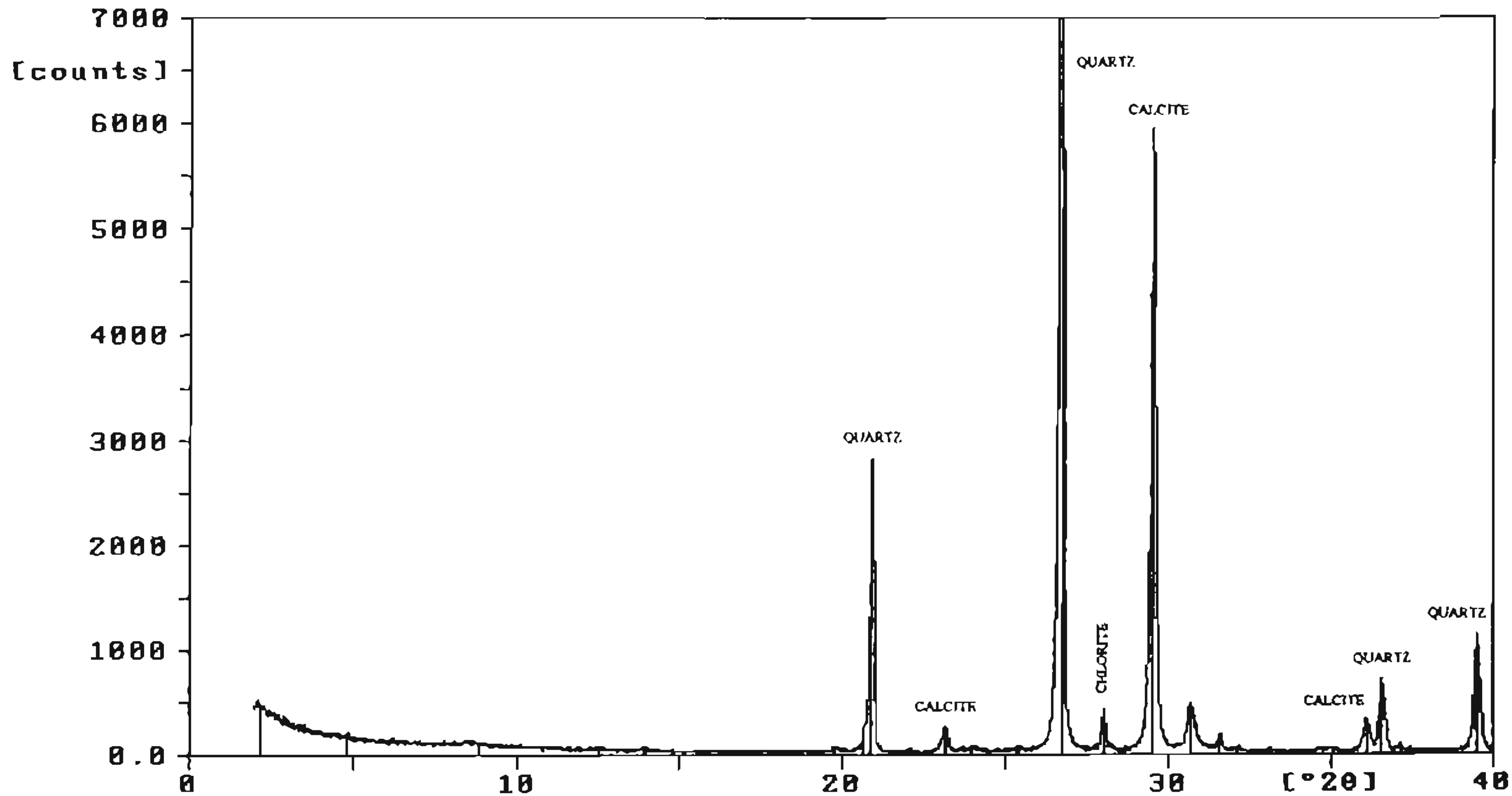
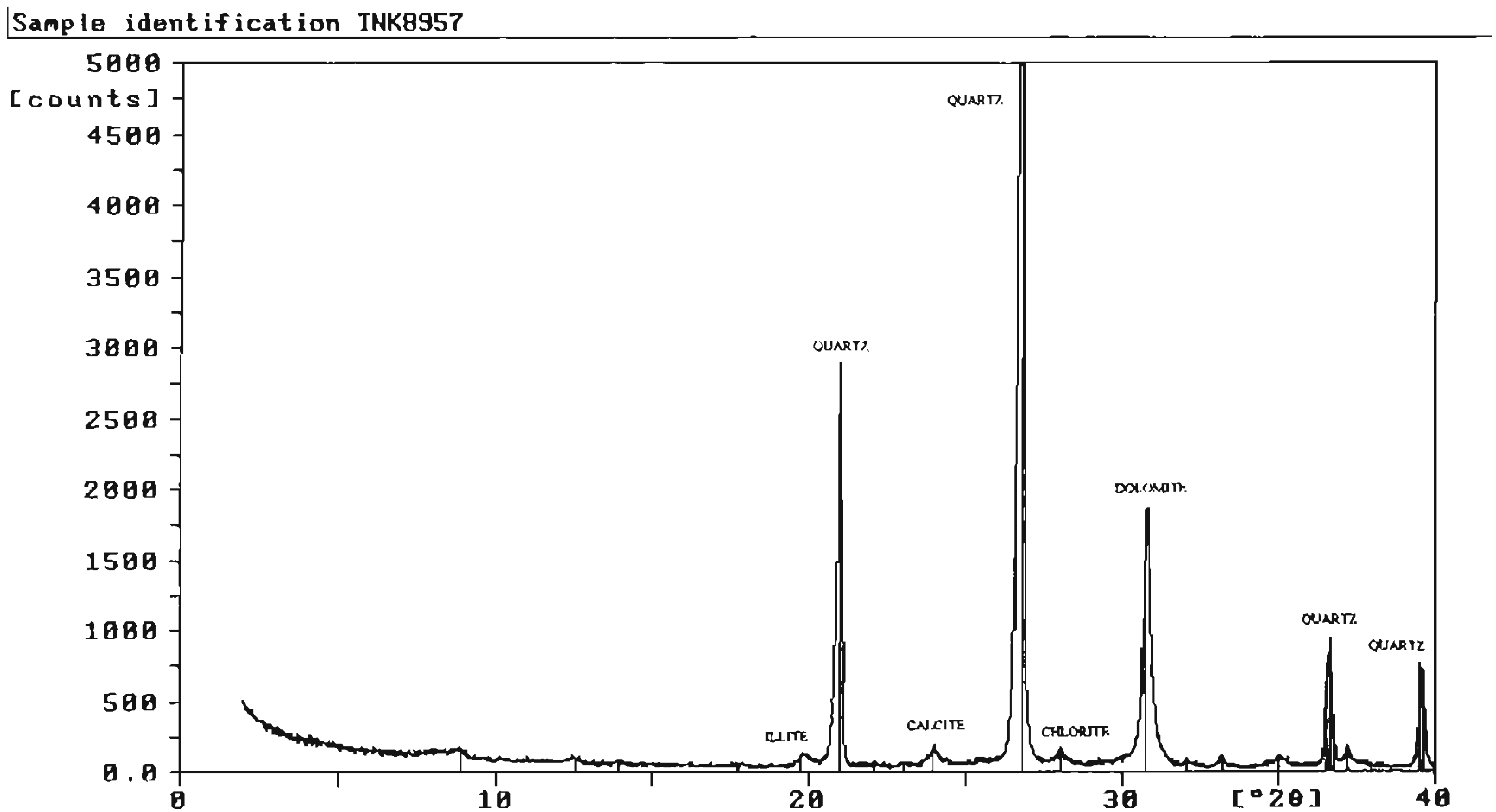
QUARTZ

Sample identification INK8955

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DOLOMITE
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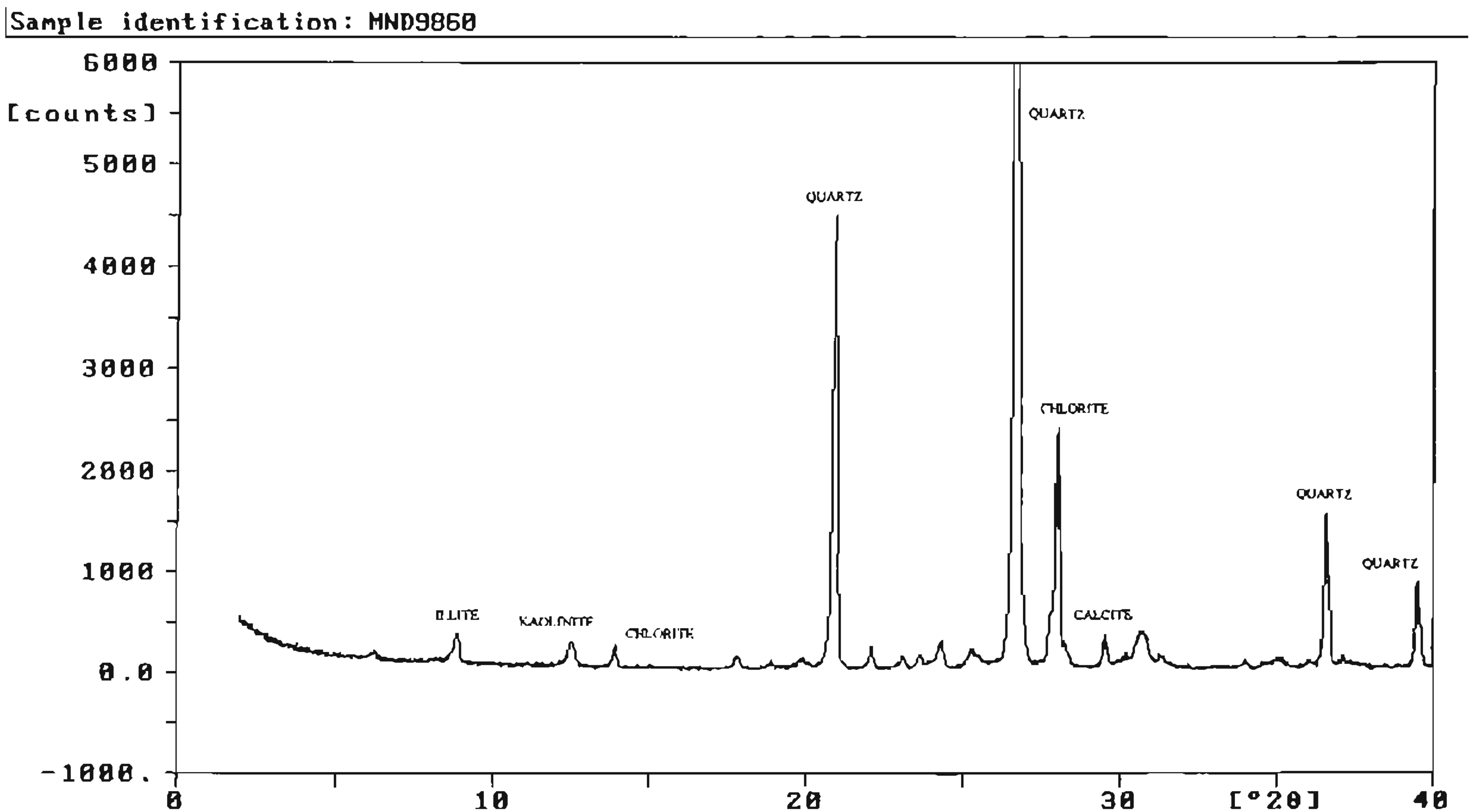
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QUARTZ
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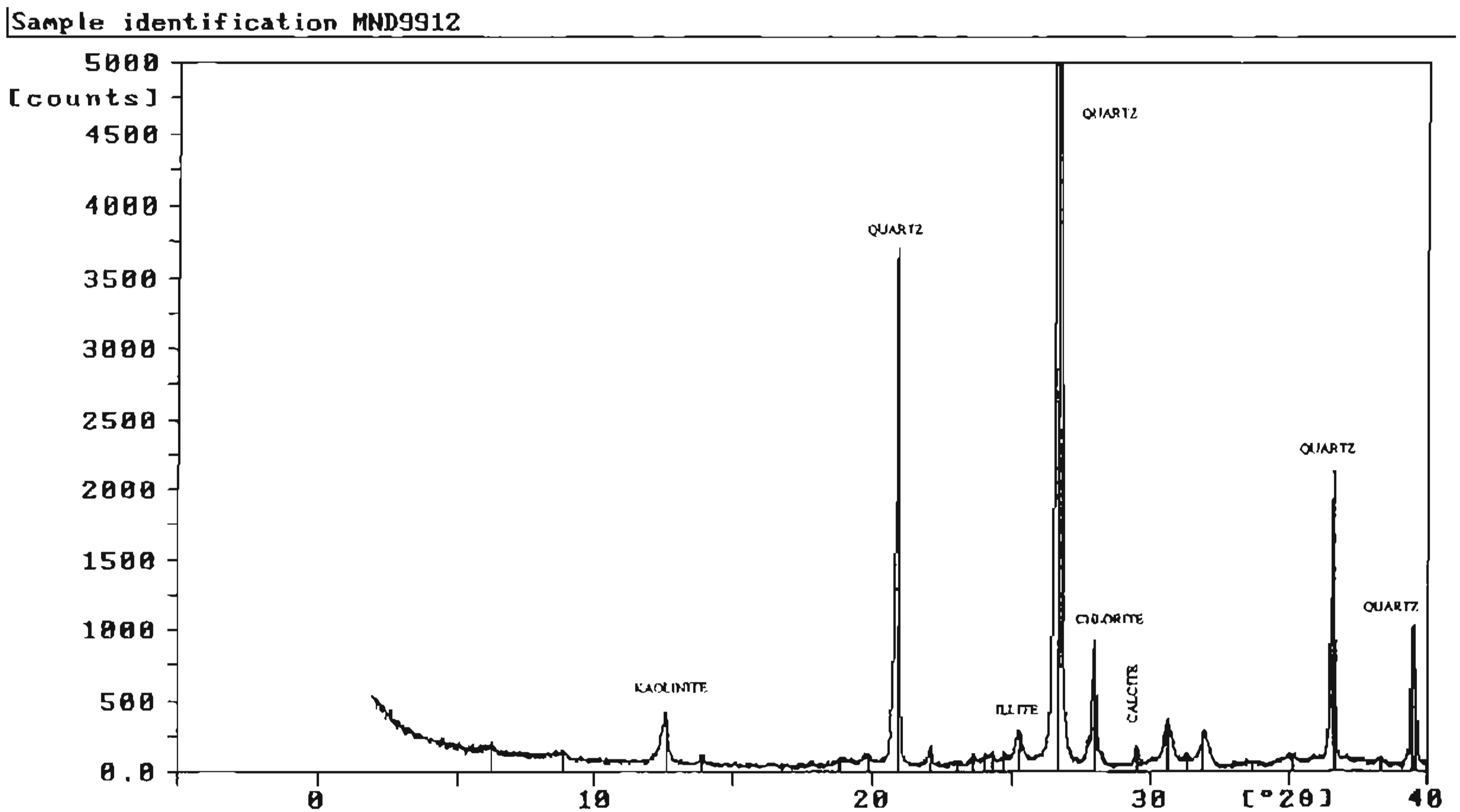
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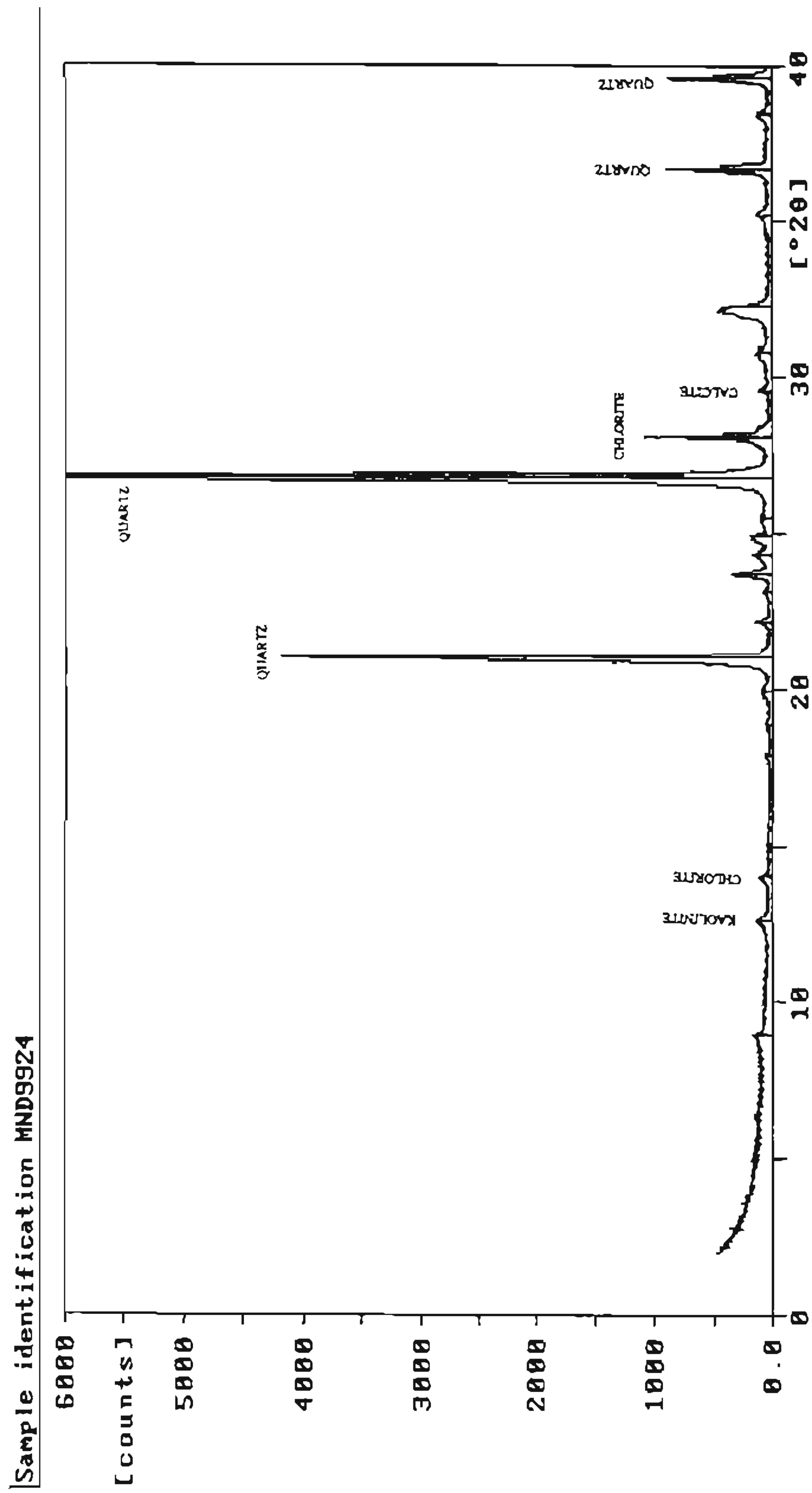
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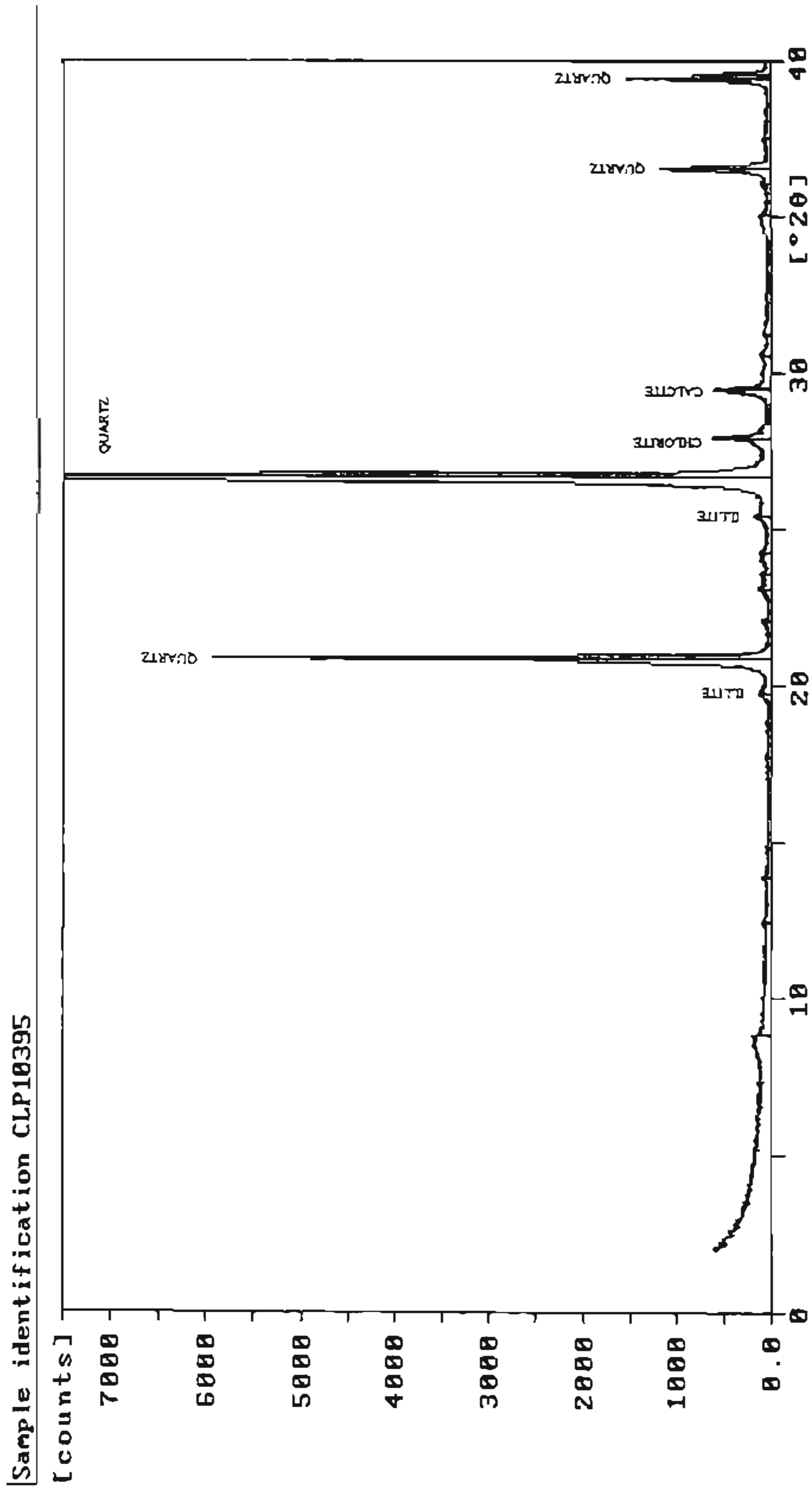

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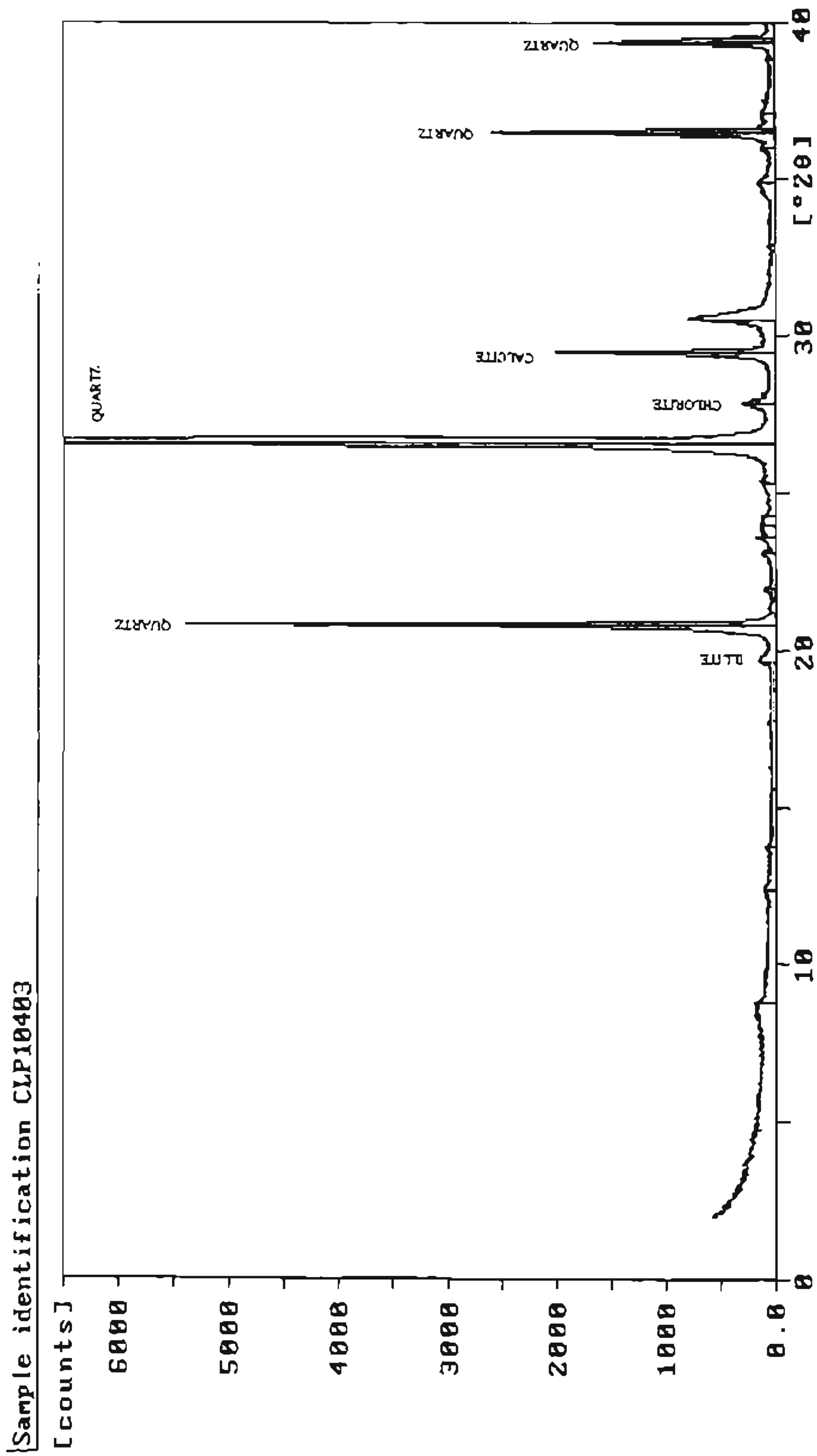
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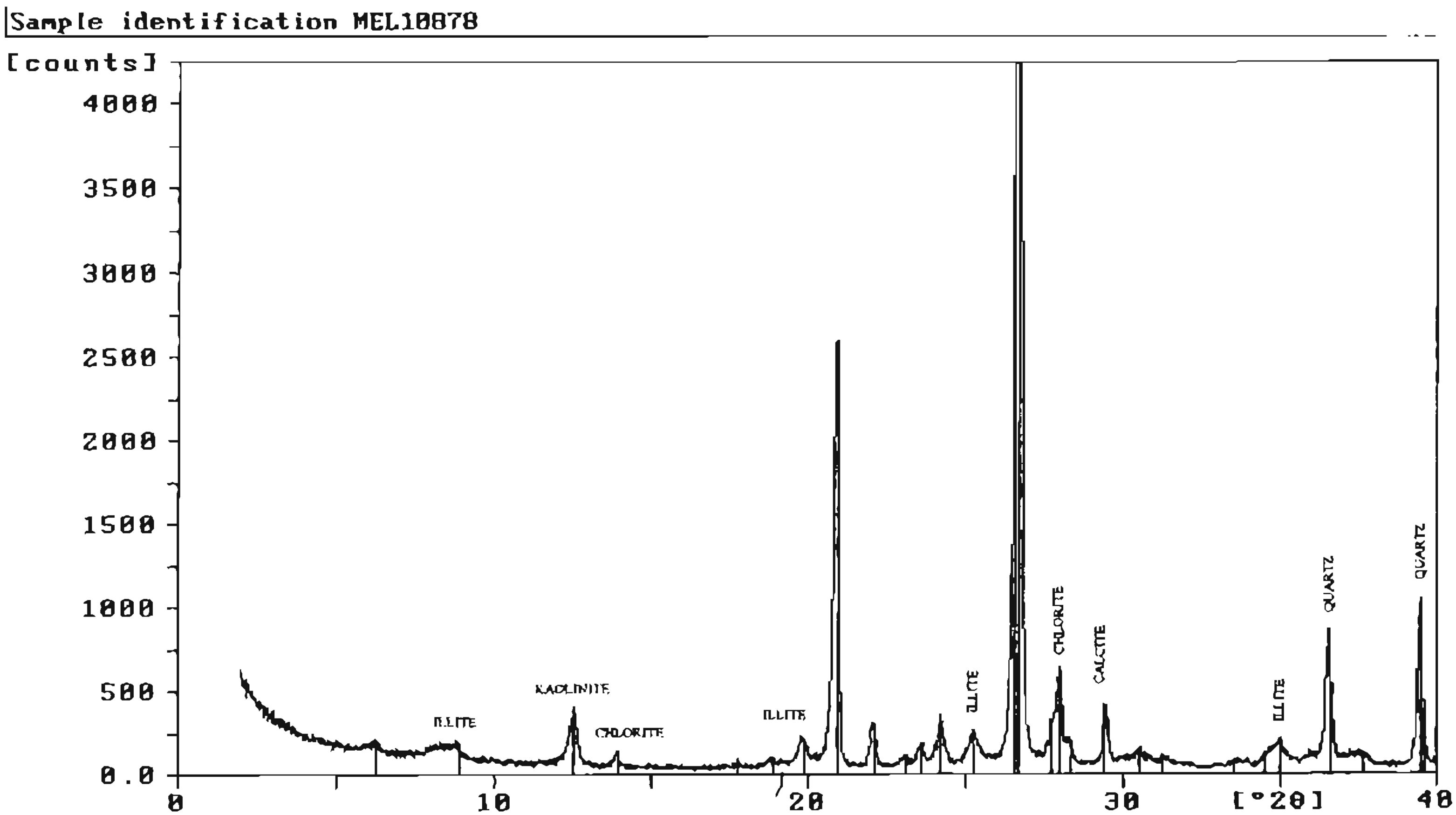
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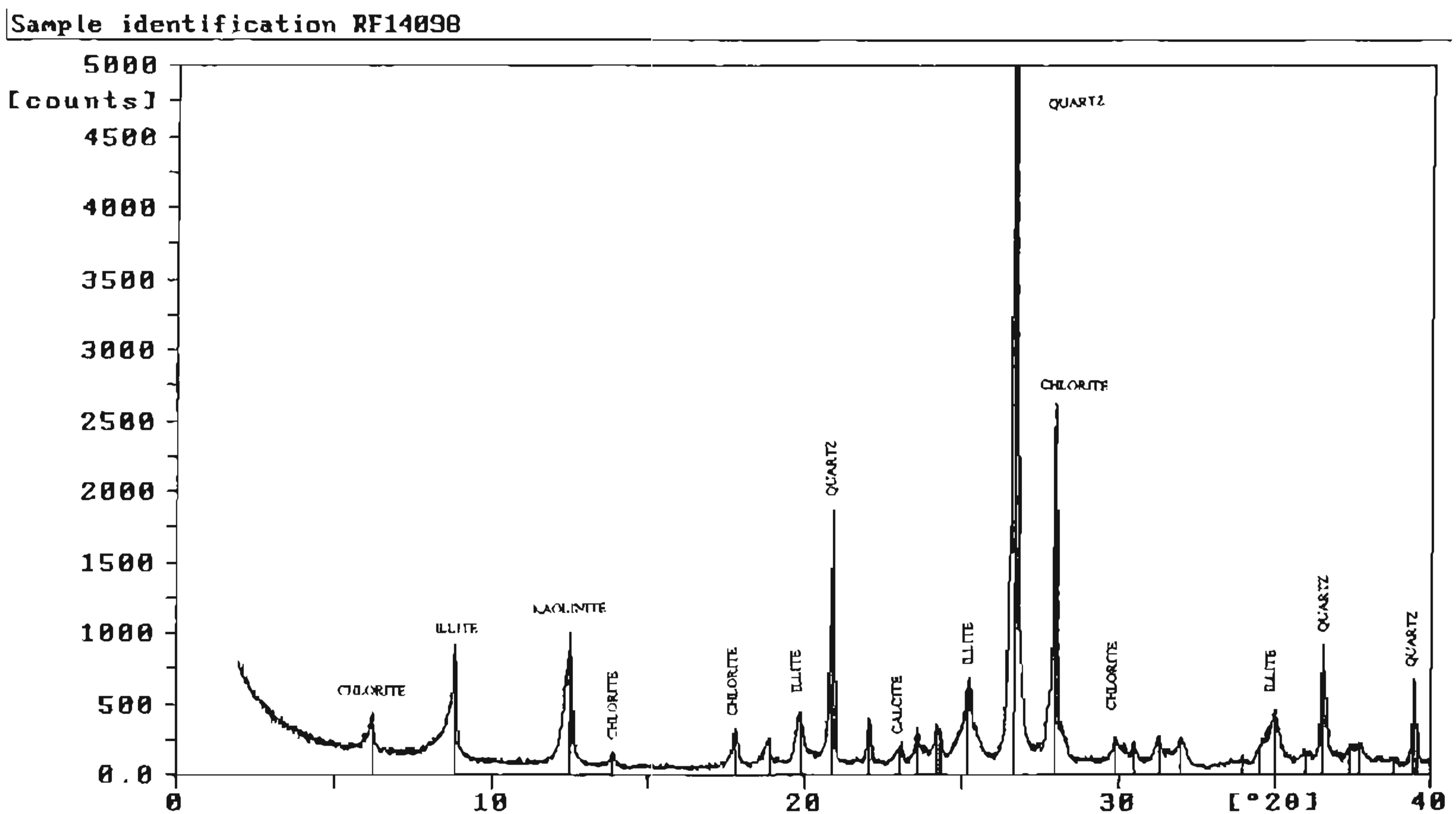
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ILLITE
KAOLINITE
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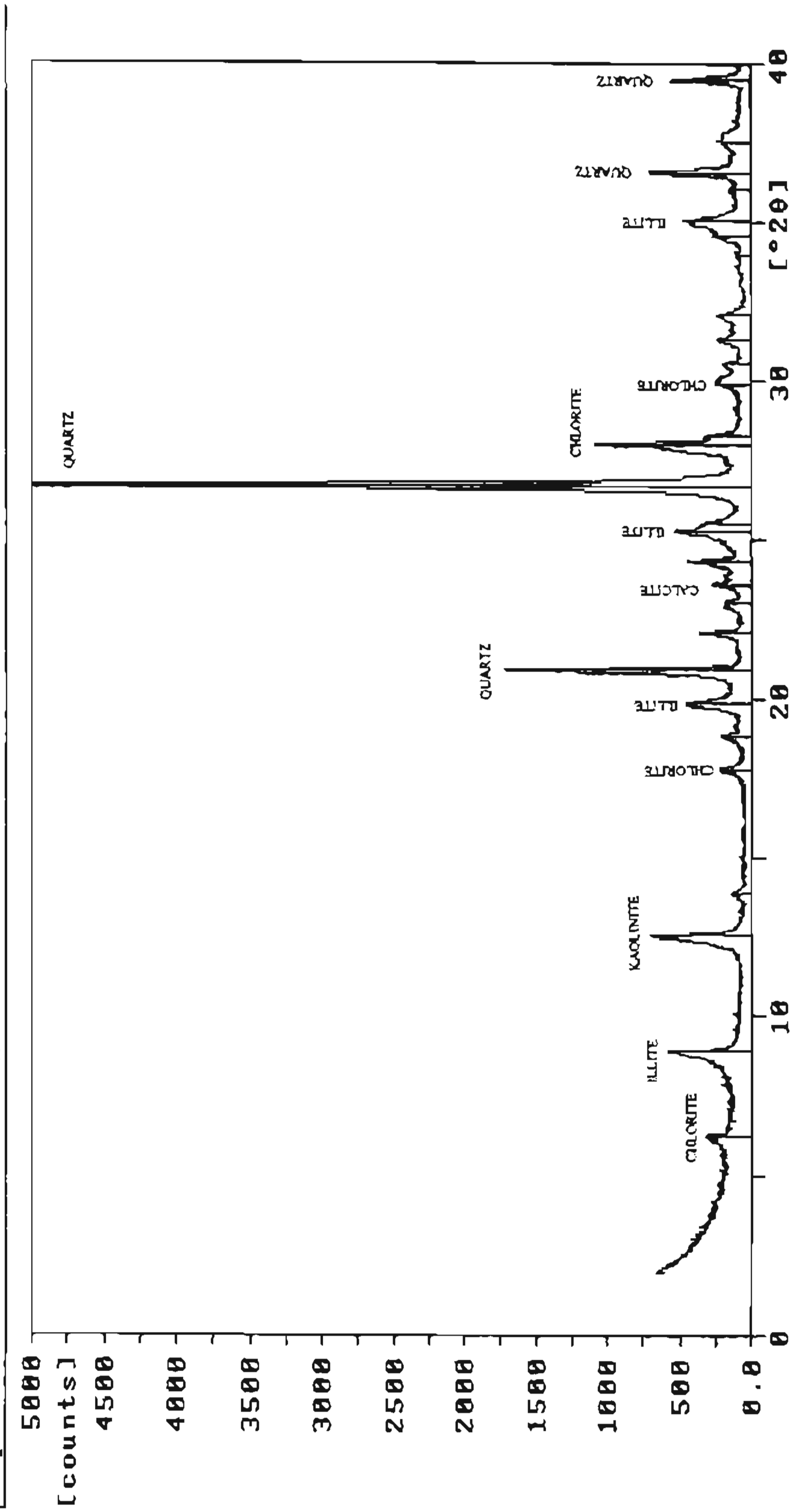

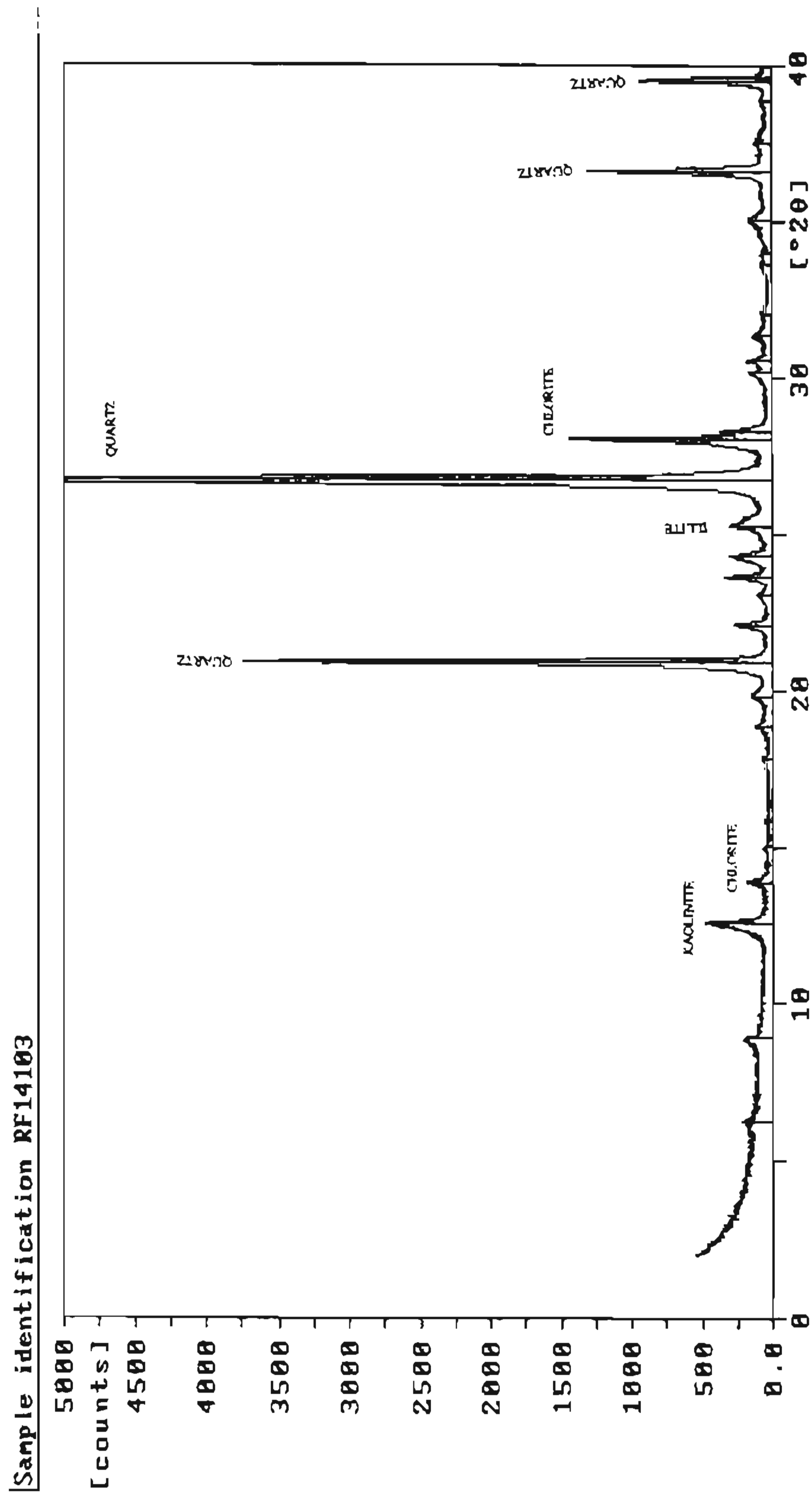
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CHLORITE
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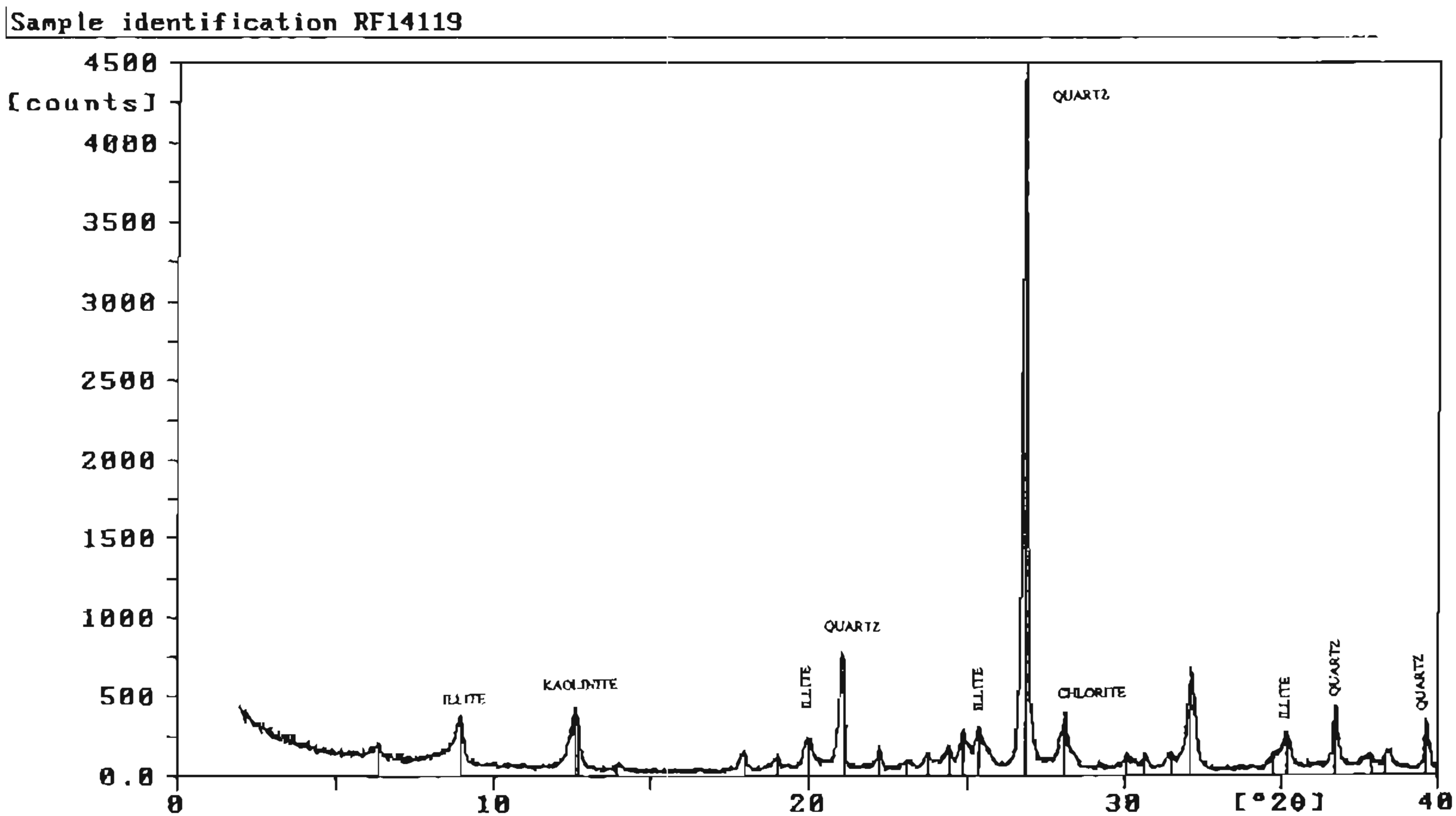
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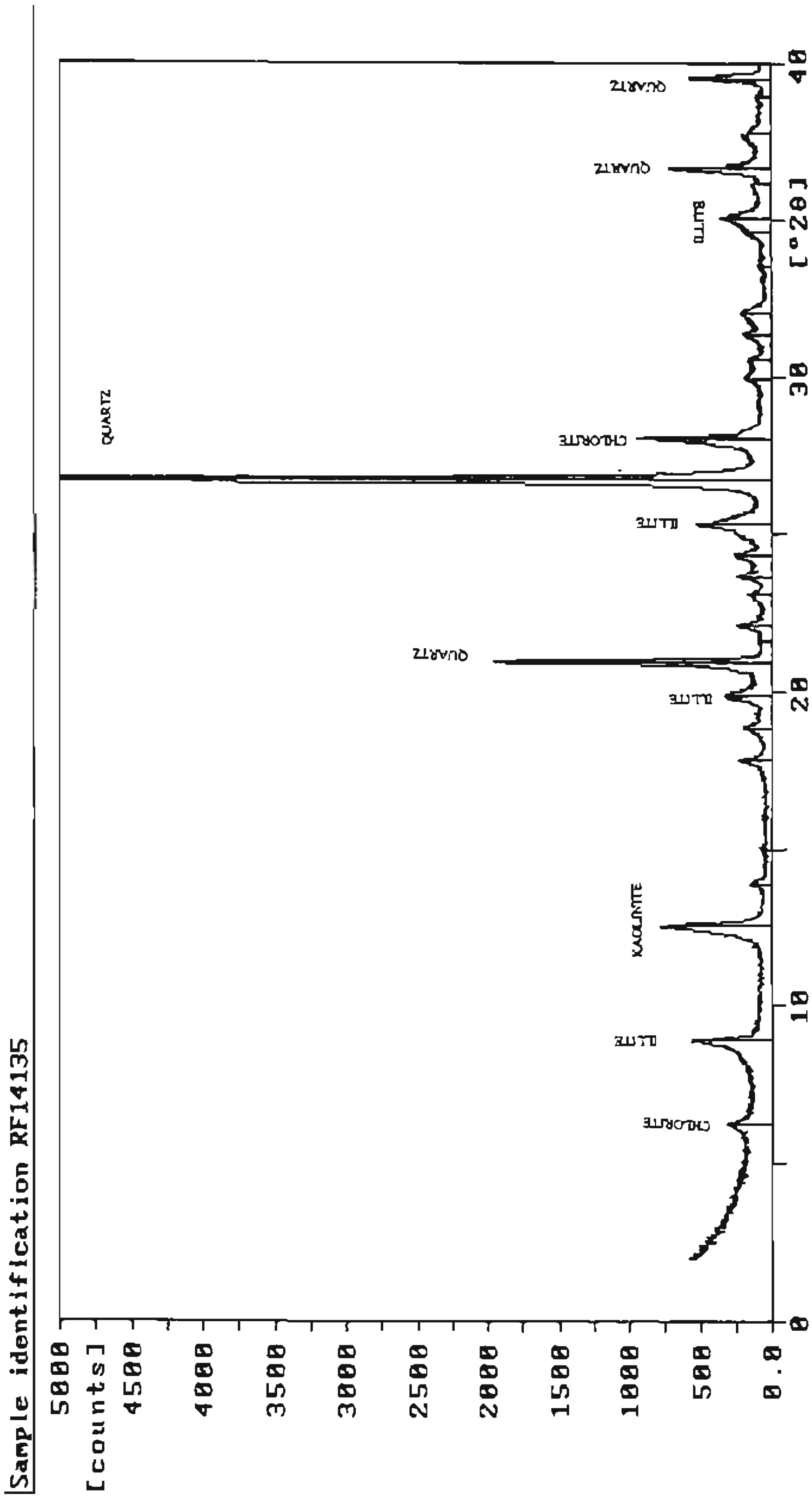
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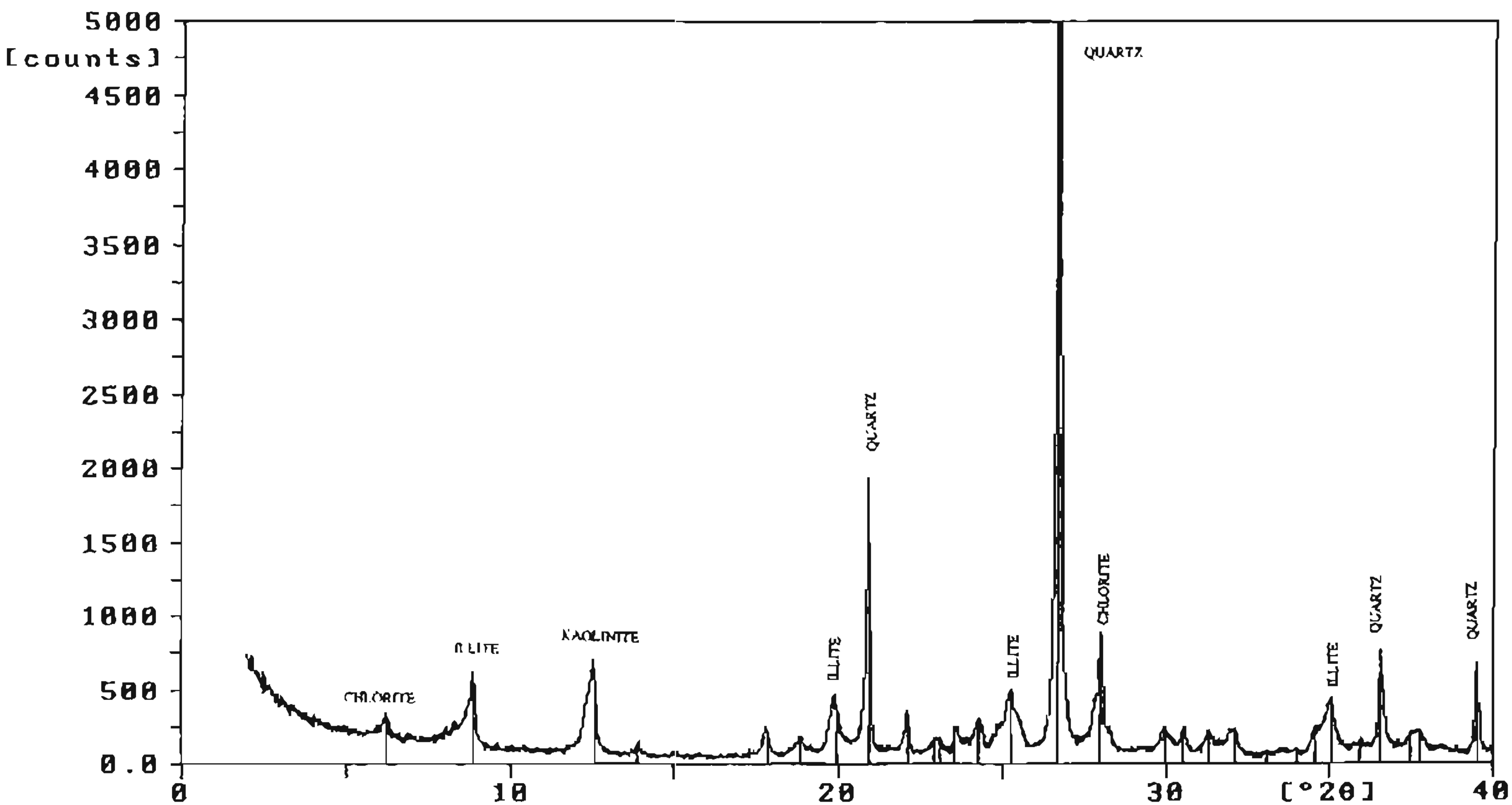
Sample identification RF14144



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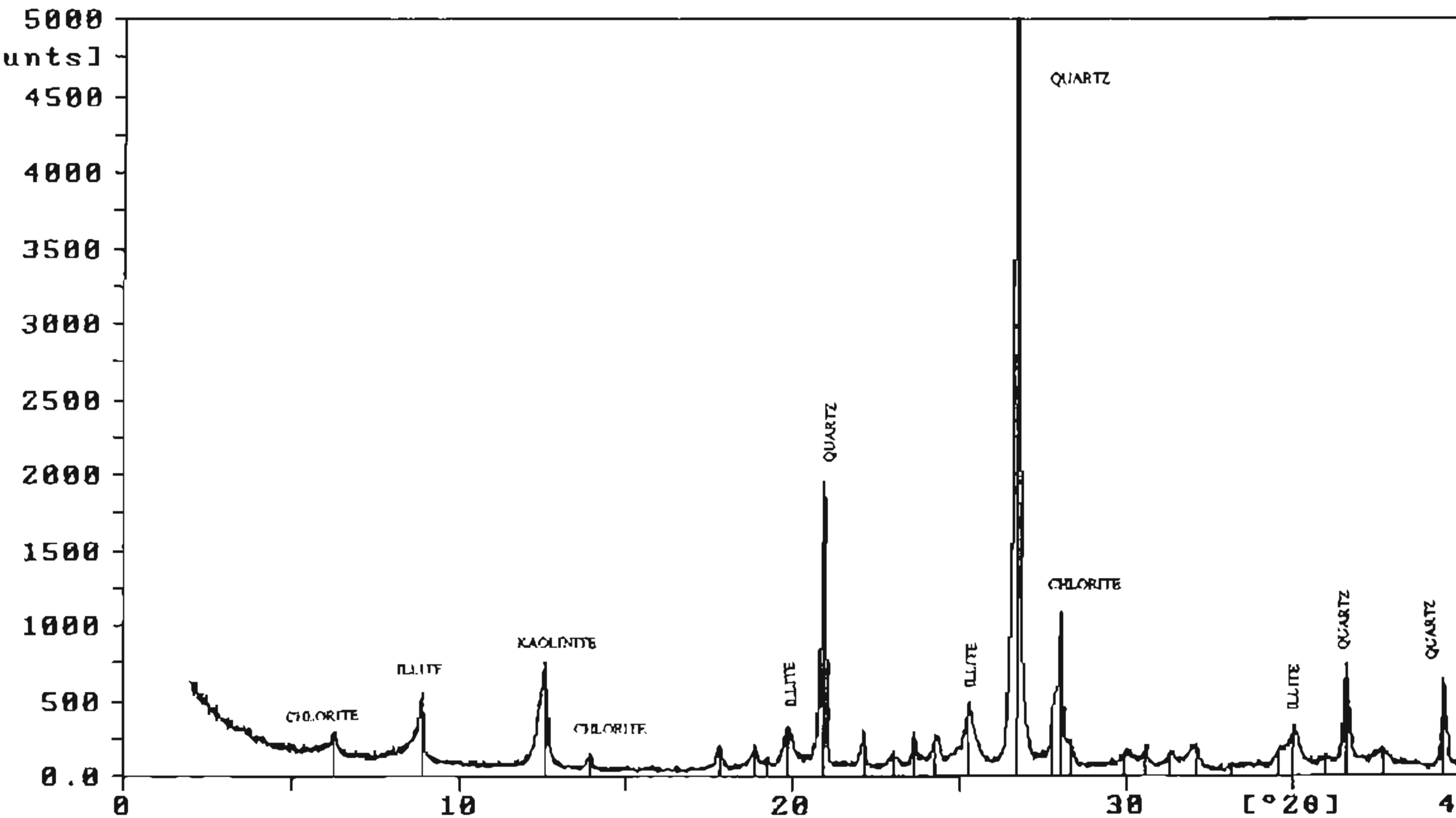

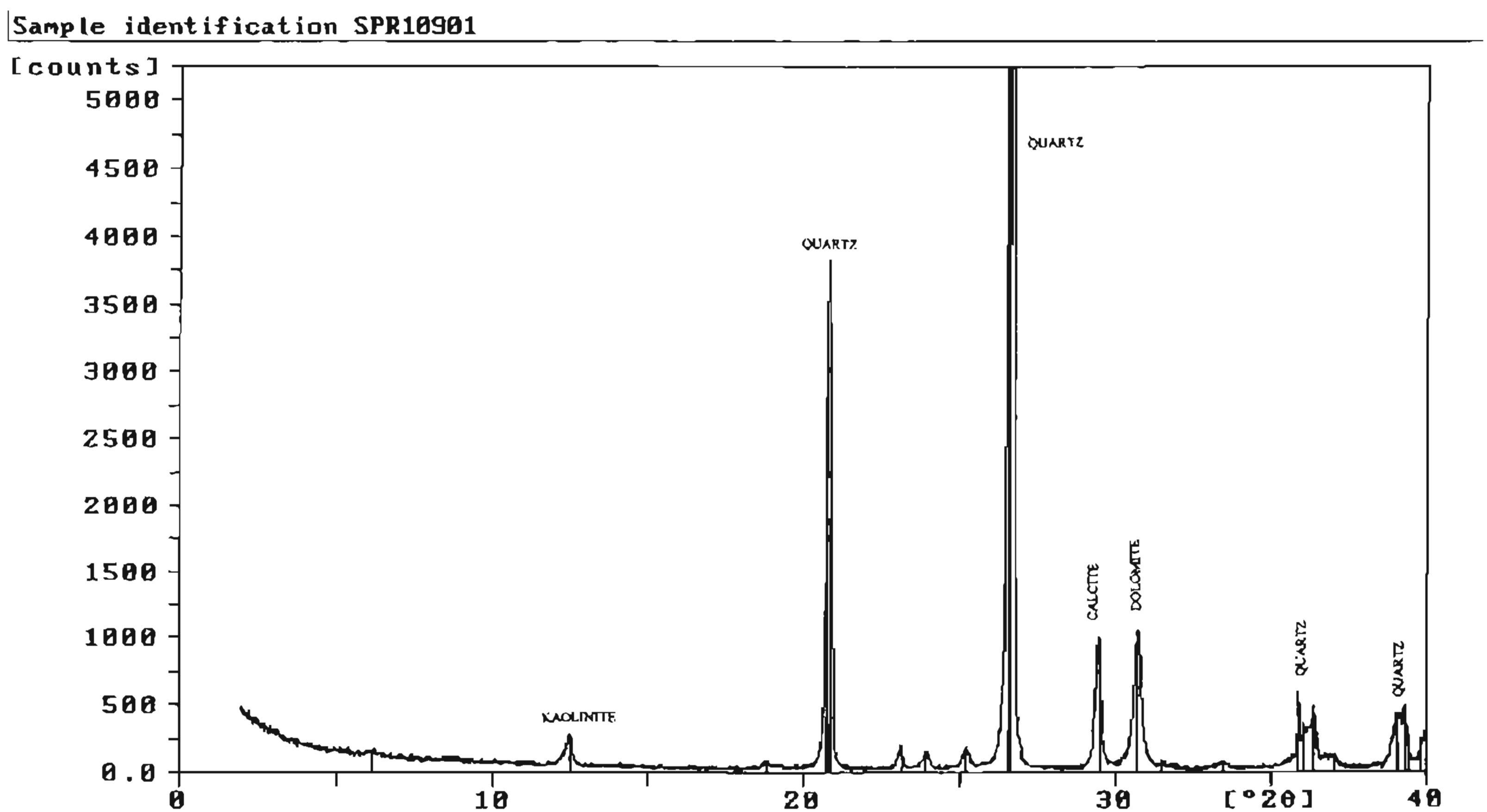

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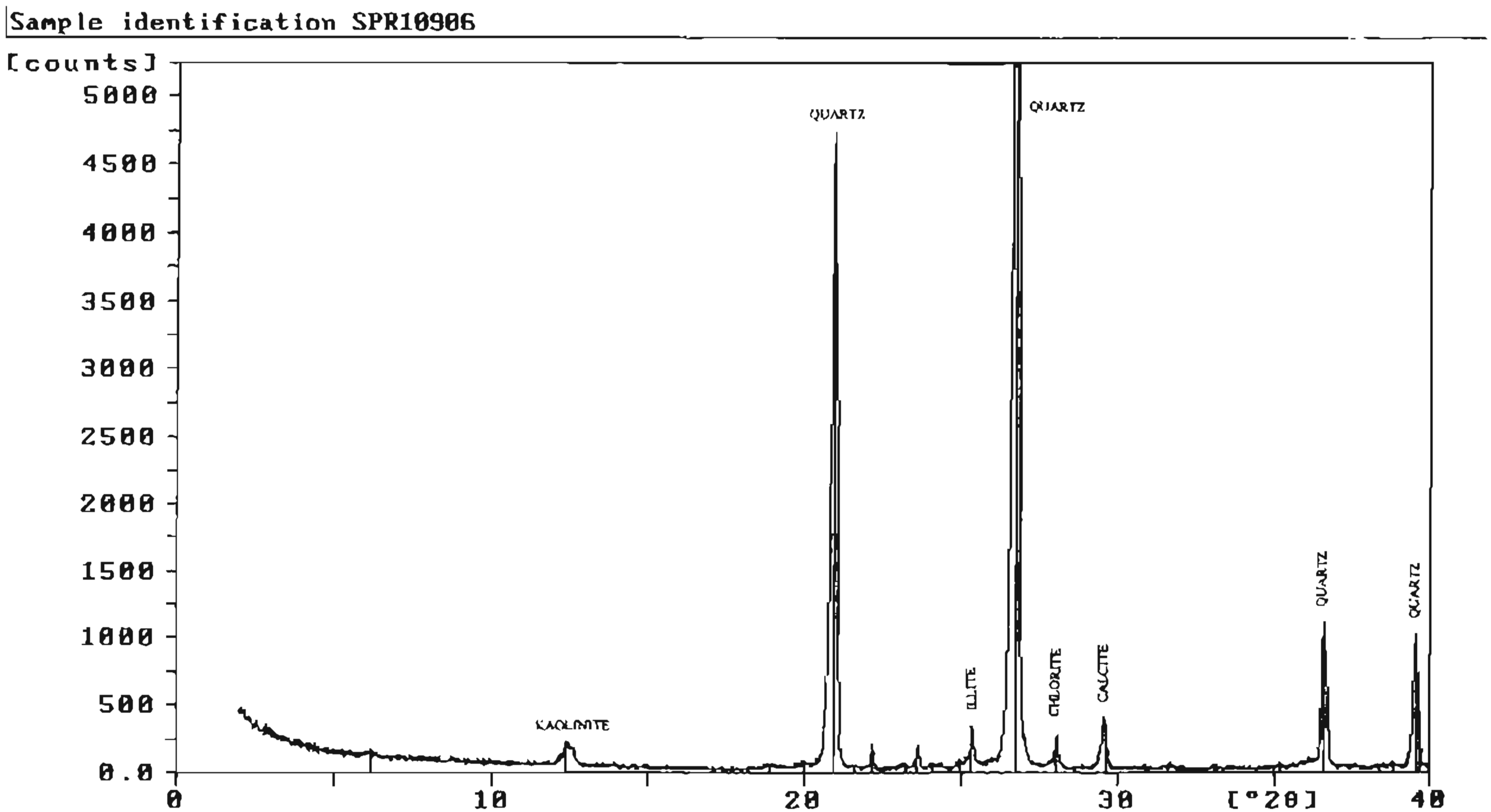
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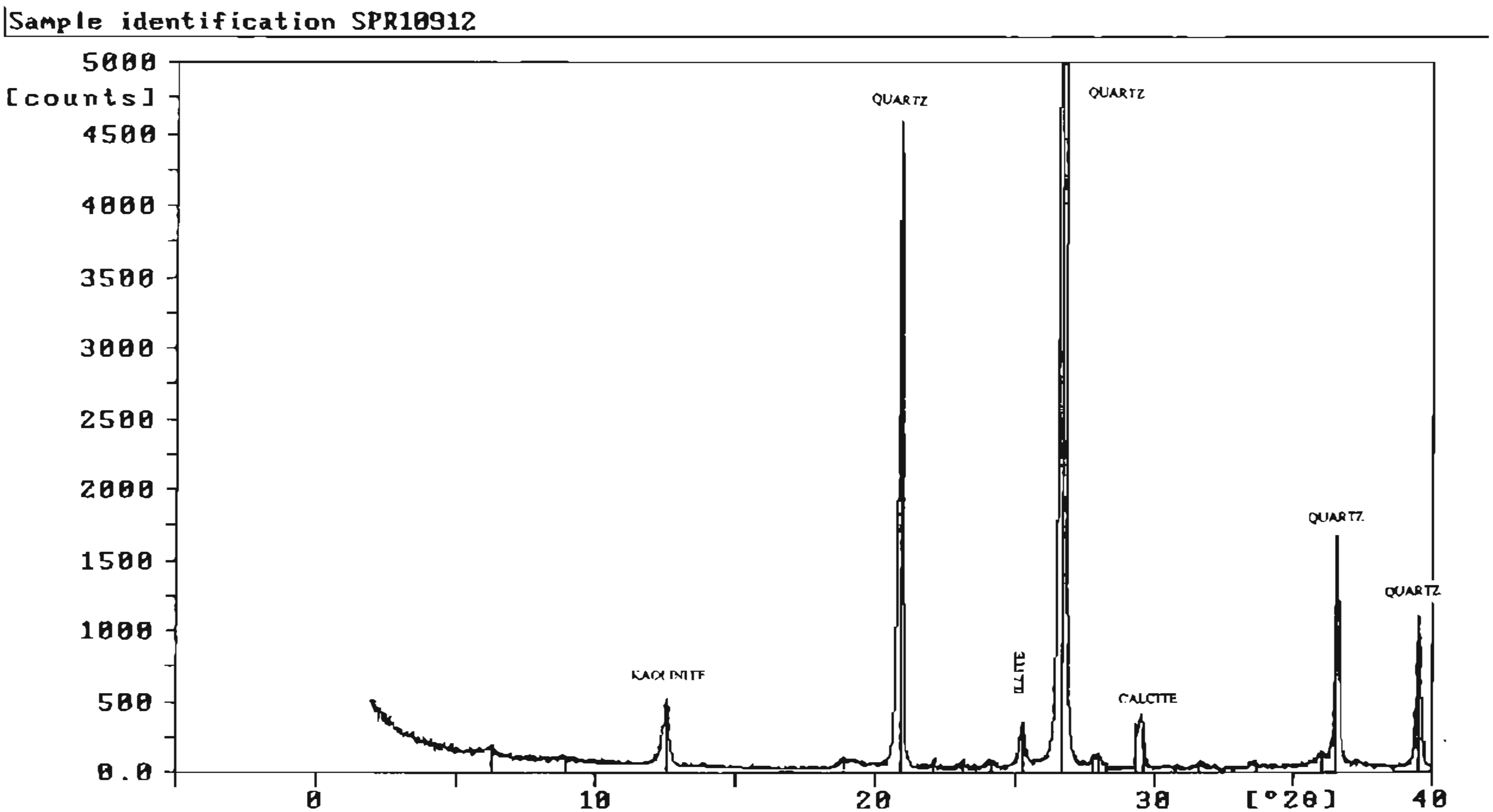
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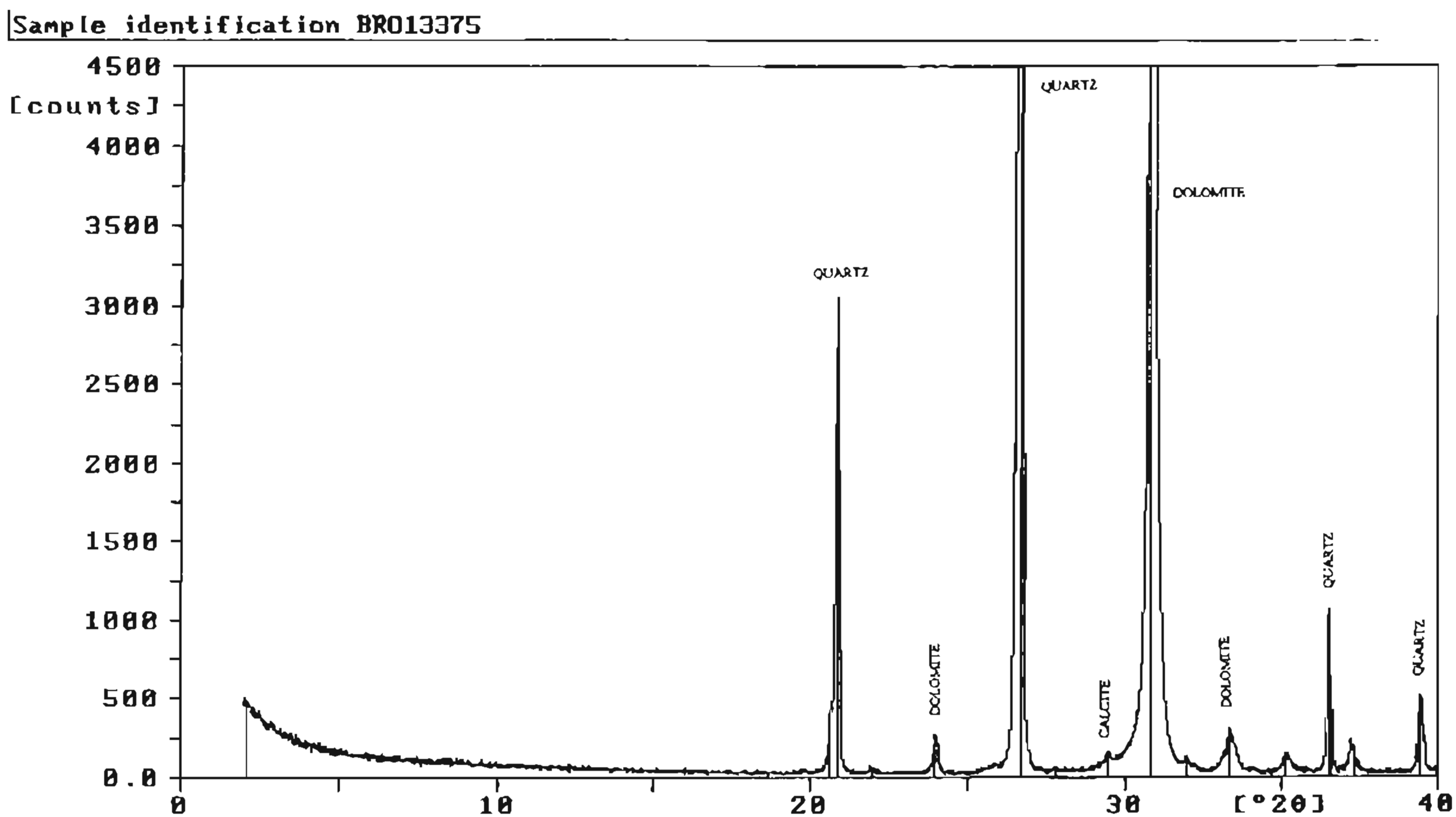
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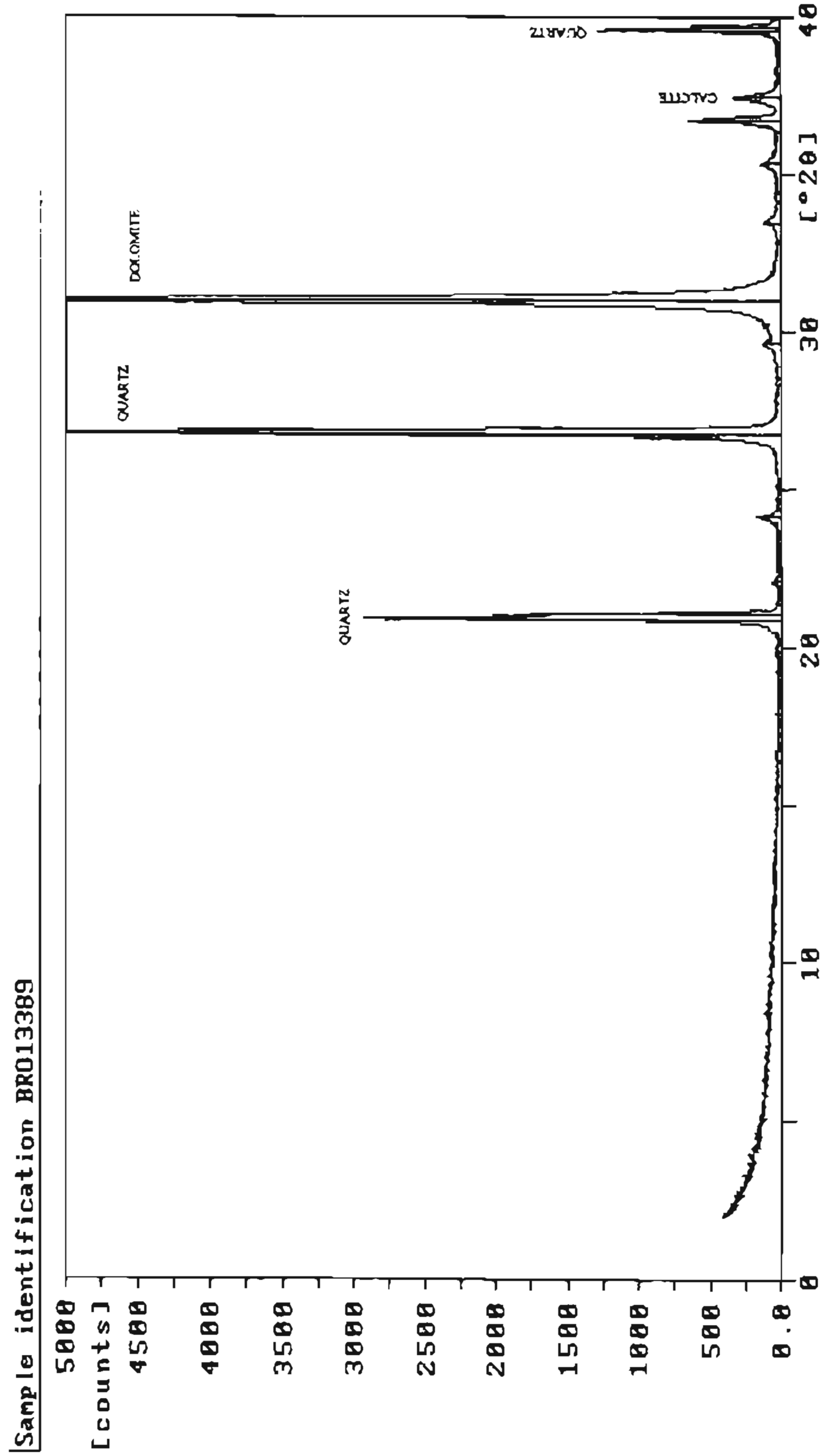
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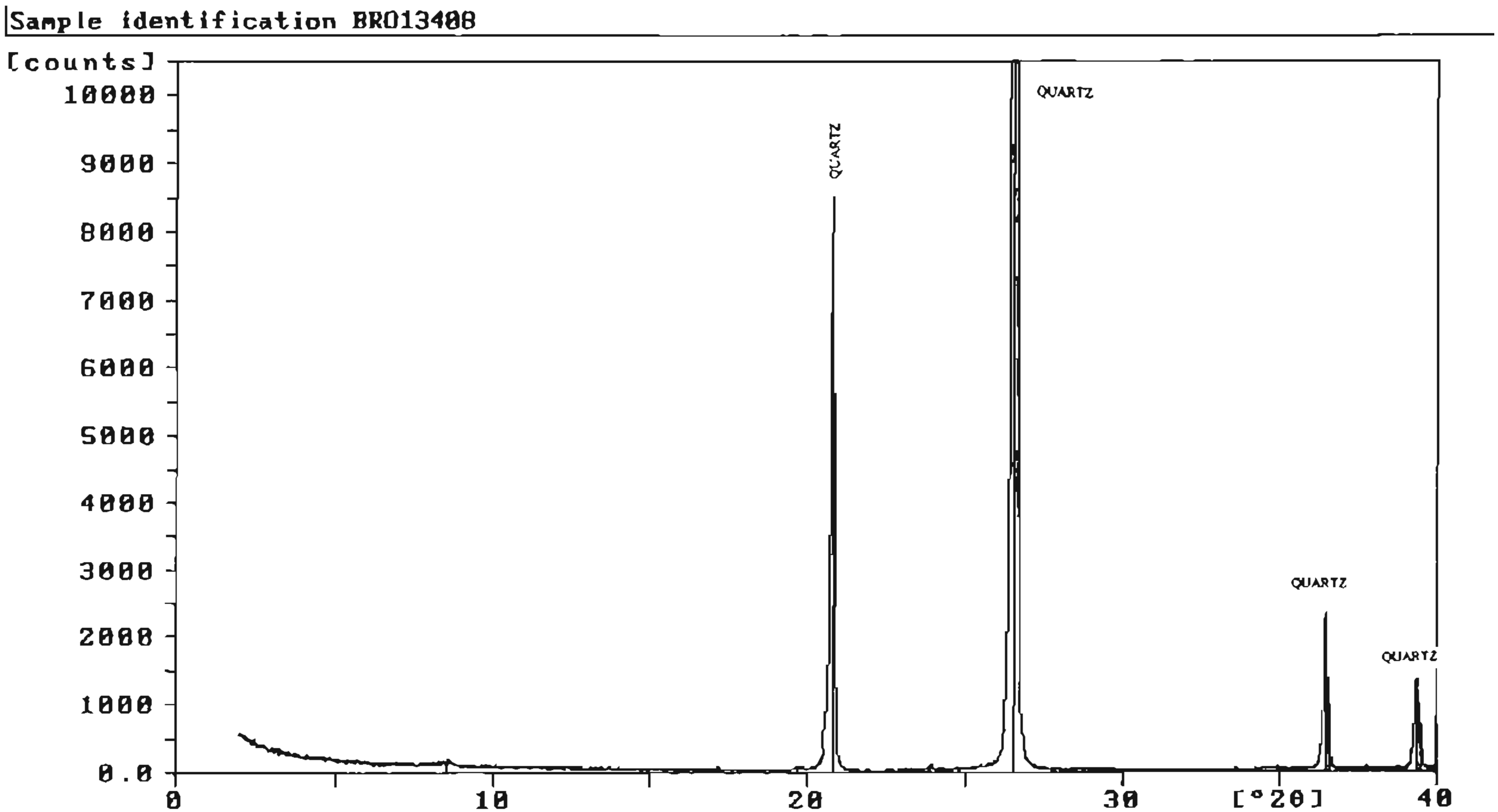
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[°2θ]
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QUARTZ
QUARTZ
QUARTZ

APPENDIX E

SEALING MECHANISMS (CONSTITUENTS AND PROCESSES)

SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
FORTUNA	2035	38	0.1-0.15	1 to 2			CLAYEY

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	QD %
FORTUNA	2035	27.8	PRIMARY SECONDARY	39.2 2	K, I, C	ALLUVIAL	4.8	2.4

K = KAOLINITE M-C = MECHANO-CHEMICAL
I = ILLITE QP = QUARTZ PRECIPITATION
C = CHLORITE QP = QUARTZ DISSOLUTION

SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
TONKAWA	8953	69	0.2-0.5	2 to 5	CALCITE	10.2	CLAYEY
	8955	54.6	0.15-0.5	2 to beg. 5	CALCITE	35.2	
					DOLOMITE	T	
	8957	72.4	0.15-0.5	2 to beg. 5	CALCITE	5	CLAYEY
					DOLOMITE	T	

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	QD %
TONKAWA	8953	8	SECONDARY	T	K, I, C	SHELF	17.5	7.0
	8955		SECONDARY	0.8	C		10.75	7.5
	8957	7	SECONDARY	T	K, I, C		14.25	5.25

K = KAOLINITE M-C = MECHANO-CHEMICAL
I = ILLITE QP = QUARTZ PRECIPITATION
C = CHLORITE QP = QUARTZ DISSOLUTION

SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
MARCHAND	9860	74.8	0.05-0.23	3 to 5	CALCITE	4.2	
	9912	68.4	0.1-0.3	3 to 5	CALCITE	19.2	CLAYEY
	9924	74.4	0.09-0.3	3 to 5	CALCITE	4.4	

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	 QD %
MARCHAND	9860		PRIMARY	0.2				
			SECONDARY	0.8	K, I, C	SHELF/SLOPE	10.33	4.7
	9912	9	SECONDARY	T	K, I, C		13.25	5.5
	9924		PRIMARY	11.6				
			SECONDARY	T	K, I, C		9.75	4.75

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SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
CULP	10395	82.6	0.15-0.45	3 to 5	CALCITE	4.4	
	10403	74 2	0.1-0.35	3 to 5	CALCITE	13.8	

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	QD %
CULP	10395		SECONDARY	3.8	K, I, C	SHELF-DELTA	9.75	4.75
	10403		SECONDARY	4	K, I, C		12.25	3.75

K = KAOLINITE M-C = MECHANO-CHEMICAL
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SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
MELTON	10878	74.2	0.1-0.2	3 to 5	CALCITE	5.8	

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	QD %
MELTON	10878		SECONDARY	0.6	K, I, C	SLOPE	7.25	5.5

K = KAOLINITE M-C = MECHANO-CHEMICAL
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SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE	
REDFORK	14098	33.6	0.02-0.1	1 to 2	CALCITE	T	CLAYEY	
	14101	36	0.02-0.1	1 to 3	CALCITE	0.4	CLAYEY	
	14103	57.4	0.02-0.1	1 to 3	CALCITE	T	CLAYEY	
	14119	40	0.02-0.1	0 to 1	CALCITE	T	CLAYEY	
	14135	46	0.02-0.2	1 to 3	CALCITE	1	CLAYEY	
	14144	15.4	0.04-0.1	0 to beg. 2	CALCITE	T	CLAYEY	
	14147	37	0.03-0.25	1 to 3	CALCITE	9	CLAYEY	
SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	QD %
REDFORK	14098	17.8	SECONDARY	1	K, I, C	SUB-FAN	3.75	1.5
	14101	13	SECONDARY	0.6	K, I, C		3.5	2.5
	14103	7.2	SECONDARY	T	K, I, C		7.75	3.0
	14119	12	SECONDARY	T	K, I, C		2.25	1.75
	14135	3	SECONDARY	T	K, I, C		3.0	1.75
	14144	18.4	SECONDARY	T	K, I, C		1.75	1.25
	14147	13.4	SECONDARY	T	K, I, C		5.0	2.25

K = KAOLINITE M-C = MECHANO-CHEMICAL
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SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
SPRINGER	10901	56.2	0.1-0.4	4 to 5	CALCITE	39.2	
	10906	72.6	0.01-0.2	3 to 5	CALCITE	T	
	10912	59.4	0.1-0.35	3 to 5	CALCITE	17.6	
					DOLOMITE	T	

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	QD %
SPRINGER	10901		PRIMARY	4	K, I	SHELF		
			SECONDARY	2			9.2	4.25
	10906		PRIMARY	14.2	K, I, C			
			SECONDARY	2			7.25	4.5
	10912		PRIMARY	16 6	K, I, C			
			SECONDARY	3			11.75	4.25

K = KAOLINITE M-C = MECHANO-CHEMICAL
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SANDSTONE	DEPTH feet	QUARTZ AMOUNT %	QUARTZ SIZE mm	QUARTZ CONTACT stage	CEMENT TYPE	CEMENT AMOUNT %	MATRIX TYPE
BROMIDE	13375	75.8	0.35-0.75	3 to 5	CALCITE DOLOMITE	11.8 5.4	
	13389	54.4	0.2-0.85	3 to 5	CALCITE DOLOMITE	2 4 43.2	
	13408	94.6	0.2-0.5	3 to 5			

SANDSTONE	DEPTH feet	MATRIX AMOUNT %	POROSITY TYPE	POROSITY AMOUNT %	CLAYS	DEPOSITIONAL ENVIRONMENT	EVIDENCE M-C PROCESSES QP %	 QD %
BROMIDE	13375		SECONDARY	7		SHELF/ PLATFORM	13.75	8.0
	13389		SECONDARY	T			14.75	4.75
	13408		PRIMARY SECONDARY	4.2 T			9.75	4.75

K = KAOLINITE M-C = MECHANO-CHEMICAL
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APPENDIX F

SANDSTONE LOCATION WITH RESPECT TO THE MEGACOMPARTMENT COMPLEX

DEPTHS (FT) FOR THIS STUDY	BURIAL DESIGNATIONS FOR THIS STUDY	SANDSTONE	LOCATION WITH RESPECT TO MCC	
2,000	SHALLOW	FORTUNA	SIGNIFICANTLY ABOVE TOP SEAL	
8,900 10,500	MODERATE	TONKAWA MARCHAND CULP MELTON	IMMEDIATELY ABOVE TOP SEAL	
10,900	DEEP	RED FORK SPRINGER	WITHIN THE MCC	TOP SEAL MEGACOMPARTMENT COMPLEX BASAL SEAL
14,150		BROMIDE	BELOW THE BASAL SEAL	

VITA

Kelly Lynn Thurman

Candidate for the Degree of

Master of Science

Thesis: DIAGENETIC CHARACTERISTICS OF SELECTED SANDSTONES ABOVE, WITHIN, AND BELOW THE MEGACOMPARTMENT COMPLEX, ANADARKO BASIN, OKLAHOMA

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